Division of Mineral Resources

VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. I-A

Annual Report
ON THE
Mineral Production of Virginia
During the Calendar Year
1908

BY
THOMAS LEONARD WATSON.

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THOMAS LEONARD WATSON, Ph. D.
Director of the Survey, and Professor of Economic Geology in the University of Virginia

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CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA
1909

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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, December 1, 1909.

To His Excellency, Hon. Claude A. Swanson, Governor of Virginia and Chairman of the State Geological Commission:

SIR:—I have the honor to transmit herewith for publication, as Bulletin No. I-A of the Virginia Geological Survey Series of Reports, my Annual Report on the Mineral Production of Virginia during the Calendar Year 1908. This report treats briefly of the economic geology, and gives full information descriptive of the mining industry in Virginia during the calendar year ending December 31, 1908.

The call for information relating to Virginia's mineral resources is large, and it is hoped that this report will meet in part the demand and aid in the development and utilization of the various mineral resources of our State.

Respectfully submitted,

THOMAS L. WATSON,
Director.

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INTRODUCTION

Virginia is possessed of an abundance and variety of mineral materials, many of which have been worked since early colonial days, especially the coal, iron ores, and brick clays. About 40 materials are now exploited, many of them on a large scale, which afford a basis of important commercial enterprises, and give to the State prominence in a varied and extensive mining industry. Most of the materials now produced can be developed still further with an increased production in future years. Some of these have been developed within recent years, and others still have not yet been exploited. The undeveloped mineral resources of the State are vast, and promise a greater increase in production in the future.

This bulletin, treating briefly of the mineral materials of Virginia, their distribution, occurrence, development, and production, for the year 1908, has been prepared with the hope that it will be of service to those now engaged in exploitation of our resources, or otherwise interested in them. The statistics of mineral production in Virginia for the calendar year 1908 have been collected by the Virginia Geological Survey in coöperation with the United States Geological Survey.[a] The total number of productive operations is large, including a variety of subjects, as is indicated in the tables of annual production below. The aggregate value of their output in 1908, according to returns received at the State Survey office, amounted to $17,883,822.

The statistics of production and value of the mineral resources of Virginia for 1908 are given below in tabular form. The figures are well below the totals of most of the materials recorded for 1907, and clearly indicate the effect of the recent business depression arising from the monetary troubles. The setback will undoubtedly prove, however, only temporary, as already there has been a considerable revival of the mining interests throughout the State, with every prospect of an increased production in 1909. Many operations that from necessity were suspended during 1908 have become active again and new operations are being developed.

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[a] Unless otherwise stated, all figures of production prior to 1908 in the tables of this report are taken from Mineral Resources of the United States.

The decrease in production and value of the mineral resources in 1908 over that of 1907 is especially noticeable in the larger industries, such as coal and coke, clay products, iron ores and pig iron, stone, talc and soapstone. Some of the smaller ones, on the other hand, show a marked increase. The total value of Virginia's mineral products in 1908 was $17,883,822, as compared with $25,783,656 in 1907, a decrease of $7,899,834, or 31 per cent.

There are given in the tables below the production and value of the various mineral materials in Virginia for the years 1905 to 1908, inclusive.

Mineral Production of Virginia in 1905.

Product	Unit of Measurement	Quantity	Value
Arsenic	Pounds		$ (a)
Barytes	Short tons	6,468	27,838
Clay	Short tons		
Clay products			1,994,578
Coal	Short tons	4,275,271	3,777,325
Coke	Short tons	1,499,481	2,869,452
Ammonium sulphate	Pounds		(b)
Coal tar	Gallons	691,530	21,152
Gas, illuminating	Cubic feet	420,420,478	485,368
Gas coke	Short tons	32,422	116,879
Copper	Pounds		(a)
Gold (mines report)	Fine ounces (Troy)	241	4,982
Iron ores	Long tons		(d)
Iron, pig	Long tons	510,210	[c]7,540,000
Lead	Short tons		(a)
Lime	Short tons	114,221	396,434
Manganese ores	Long tons	3,947	35,209
Marl	Short tons		(e)
Millstones			8,186
Mineral waters	Gallons	2,340,287	549,102
Pyrite	Long tons	123,183	426,008
Sand and gravel	Short tons	351,115	154,580
Silver (mines report)	Fine ounces (Troy)	177	107
Slate			146,786
Stone			667,050
Talc and soapstone	Short tons		(d)
Other products			[d]2,530,950
Total value			$21,751,986

---

[a] Included under miscellaneous.

[b] Included under West Virginia.

[c] Estimated.

[d] Includes asbestos, cement, gypsum, iron ores, metallic paint, ocher, pottery, salt, sand-lime brick, talc, and titanium.

[e] Included under New Jersey.

Mineral Production of Virginia in 1906.

Product	Unit of Measurement	Quantity	Value
Barytes	Short tons	11,775	$ 45,336
Clay	Short tons	2,903	24,354
Clay products			1,966,078
Coal	Short tons	4,254,879	4,183,991
Coke	Short tons	1,577,659	3,611,659
Ammonium sulphate	Pounds		[a]685,738
Coal tar	Gallons		
Gas, illuminating	Cubic feet		
Gas coke	Short tons		
Gold (mines report)	Fine ounces (Troy)	717.50	14,832
Iron ores	Long tons	828,081	1,579,817
Iron, pig	Long tons	483,525	[a]8,591,000
Lime	Short tons	104,486	382,083
Manganese ores	Long tons	6,028	77,522
Millstones			15,611
Mineral waters	Gallons	1,997,207	418,908
Precious stones			500
Pyrite	Long tons	128,794	431,388
Sand and gravel	Short tons	335,178	121,951
Silver (mines report)	Fine ounces (Troy)	250	168
Slate			172,857
Stone			606,343
Talc and soapstone	Short tons	23,624	590,800
Zinc	Short tons	1,143	139,446
Other products			[b]990,432
Total value			$24,650,814

[a] Estimated.

[b] Includes asbestos, natural cement, Portland cement, gypsum, mica, ocher, pottery, quartz (flint), salt, sand-lime brick, and titanium.

Mineral Production of Virginia in 1907.

Product	Unit of Measurement	Quantity	Value
Barytes	Short tons	9,254	$ 32,833
Clay products			1,611,335
Coal	Short tons	4,710,895	4,807,533
Coke	Short tons	1,545,280	3,765,733
Ammonium sulphate	Pounds		1,165,821
Coal tar	Gallons		
Gas, illuminating	Cubic feet		
Gas, water	Cubic feet		
Gas coke	Short tons		
Copper	Pounds	57,008	11,402
Glass sand	Short tons	1,246	4,535
Gold	Fine ounces (Troy)	402	8,300
Iron ores	Long tons	786,856	1,538,920
Iron, pig	Long tons	478,771	8,963,000
Lead	Short tons	82	8,692
Lime	Short tons	115,155	447,307
Manganese ores	Long tons	4,604	56,469
Mica			1,014
Millstones			4,684
Mineral waters	Gallons	2,442,075	431,770
Precious stones			520
Pyrite	Long tons	124,740	372,586
Sand and gravel	Short tons	266,976	119,277
Silver	Fine ounces (Troy)	200	100
Slate			173,670
Stone			760,488
Talc and soapstone	Short tons	26,278	631,880
Zinc	Short tons	771	90,978
Other products			[a]774,809
Total value			$25,783,656

[a] Includes natural and Portland cement, feldspar, gypsum, ocher, rutile, and sand-lime brick.

Mineral Production of Virginia in 1908.

Product	Unit of Measurement	Quantity	Value
Clay	Short tons	442	$ 3,250
Clay products			1,536,907
Coal	Short tons	4,259,042	3,868,524
Coke	Short tons	1,162,051	2,121,980
Ammonium sulphate	Pounds		1,180,744
Coal tar	Gallons		
Gas, illuminating	Cubic feet		
Gas, water	Cubic feet		
Gas coke	Short tons		
Copper	Pounds	24,775	3,270
Gold (mines report)	Fine ounces (Troy)	118.57	2,451
Granite			321,530
Iron ores	Long tons	692,223	1,465,691
Iron, pig	Long tons	320,458	4,578,000
Lead	Short tons	38	3,200
Lime and cement	Barrels	1,629,178	775,660
Limestone			280,542
Manganese ores	Long tons	6,418	63,324
Mica	Pounds (sheet)	13,427	7,346
	Tons (scrap)	46	
Millstones and sandstone			10,554
Mineral waters	Gallons	[a]2,009,614	207,115
Pyrite	Long tons	116,340	435,522
Sand and gravel			119,095
Sand-lime brick	Thousands	6,181	36,934
Silver	Fine ounces (Troy)	236	125
Slate	Squares	41,678	194,356
Talc and soapstone	Short tons	19,616	458,252
Zinc	Short tons	705	66,315
Other products			[b]143,135
Total value			$17,883,822

[a] Exclusive of 119,672 gallons used for soft drinks.
[b] Includes barytes, feldspar, gypsum, mineral paint, and salt.

PRELIMINARY GENERALITIES

GEOGRAPHIC POSITION OF VIRGINIA

The State of Virginia is situated on the Atlantic slope of the Appalachian Mountains, halfway between Maine and Florida. It is included between the parallels 36° 31′ and 39° 27′ north latitude, and between the meridians 75° 13′ and 83° 37′ west longitude, extending from the sea-coast westward beyond the Great Valley to the Alleghany Front. The extreme length of the State from the Atlantic border to Kentucky is 476 miles, and the greatest width from north to south is 192 miles; its area is 42,450 square miles. Of this area, 2,325 square miles are covered with water, giving 40,125 square miles of land surface. Its principal inland waters are the Chesapeake and Mobjack bays, Hampton Roads, and Lake Drummond. Except in the eastern section, no navigable streams traverse the State, and transportation is necessarily limited to railways.

SURFACE FEATURES OF THE STATE

Considered with reference to its surface features—physiography—Virginia is divided into three major provinces: (1) An eastern plain region usually designated the Coastal Plain or Tidewater region; (2) a central or plateau region designated the Piedmont Plateau; and (3) a western or mountain region, designated the Appalachian Mountains province. The boundaries of these provinces are indicated on map, figure 1, page 7.

The three larger well-defined provinces of the State differ markedly in the nature and origin of surface features, and in the age and kinds of rocks. They are intimately related to the geologic structure, and hence have an important bearing upon the mineral resources of the State. These are, therefore, considered briefly in order below.

The Coastal Plain Province

The Virginia Coastal Plain province, the most easterly of the three larger physiographic provinces, and comprising approximately one-

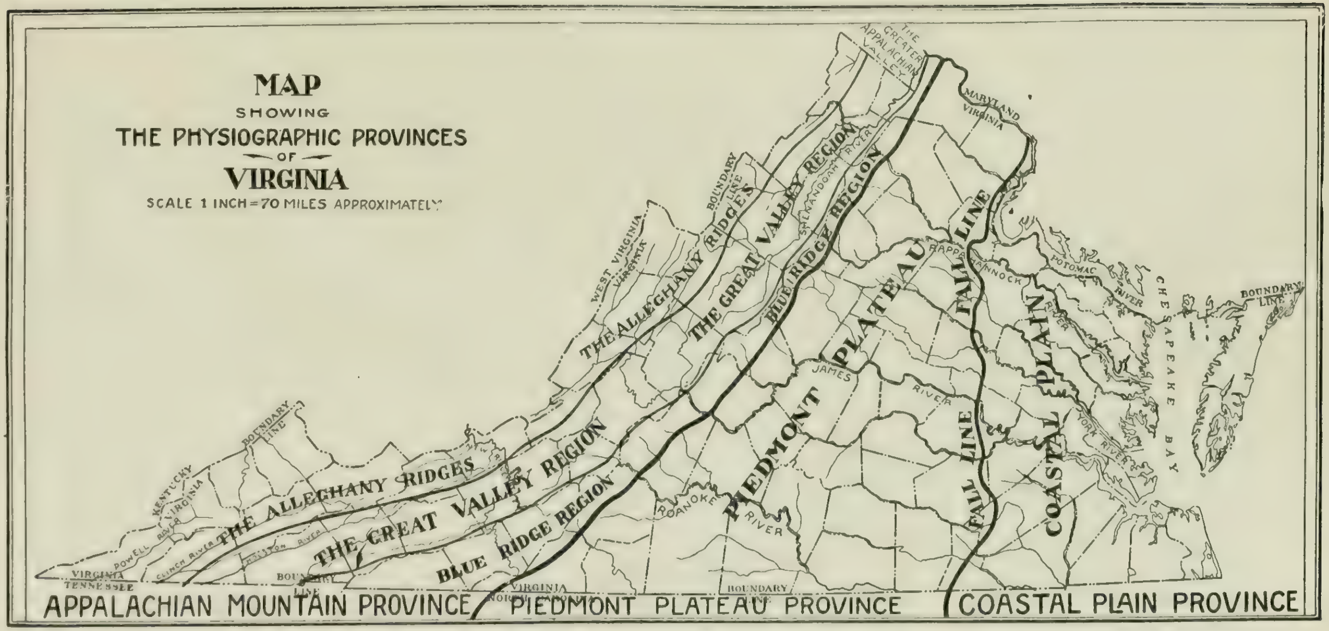


Fig. 1.—Sketch map of Virginia showing physiographic provinces.

fourth of the total area of the State, is separated from the higher-lying Piedmont Plateau province on the west and the deep Atlantic Ocean basin on the east. The boundary of the Coastal Plain to the eastward is marked by the steep slope of the continental shelf, which lies from 30 to 50 miles east of the present shore-line. The western limit of the Coastal Plain is defined by the belt of metamorphic crystalline rocks known as the Piedmont Plateau province. The Virginia Coastal Plain region is more than 100 miles wide,, and includes approximately 9,500 square miles of territory, or about one-fourth the total area of the State.

Because of marked geologic differences in the two provinces, the larger streams, and many of the smaller ones, are characterized by falls or rapids where they cross the western margin of the Coastal Plain, and they always show a marked decrease in the velocity of their currents from this point eastward. For this reason, the name "fall-line" has been given to this boundary, the position of which is marked on the accompanying map, figure 1, page 7. The position of the "fall-line," near the head of navigation and the source of water-power, has been an important factor in determining the location of many of the towns and cities of the Atlantic coast. In Virginia, the "fall-line" passes near to or through the following important cities or towns: Washington, D. C., Fredericksburg, Richmond, Petersburg, and Emporia. As indicated on the map, figure 1, the line drawn through these places approximately separates the Coastal Plain from the Piedmont Plateau. Outliers of the Coastal Plain are frequent along the eastern margin of the Piedmont province, and the older crystalline rocks of the Piedmont can be followed along the valleys of the larger streams for some distance into the Coastal Plain sediments, where the mantle of the latter has been cut through.

The Coastal Plain region, characterized by broad, level-topped stretches of country of low relief, gradually declines in slope from the Piedmont border to the shore-line. In the vicinity of Washington, elevations of more than 400 feet are reached. Southward, the western margin gradually declines in elevation to less than 200 feet in the southern portion of the State. Because of these differences in elevation, the topography is more diversified in the northern than in the southern portion of the State. Passing from these elevations along the "fall-line" or western margin, the Coastal Plain declines in slope eastward to sea-level elevations along the Coastal border. Probably the average elevation of the Virginia Coastal Plain is but slightly more than 100 feet above tide.

The formations composing the Virginia Coastal Plain are given in the table below:

Formations of Virginia Coastal Plain.

CENZOIC:		
Quaternary.		
Recent.		
Pleistocene..........	Talbot Wicomico Sunderland	Columbia Group
Tertiary.		
Pliocene............	Lafayette Norfolk	
Miocene............	Yorktown St. Mary's Choptank Calvert	Chesapeake Group
Eocene............	Nanjemoy Aquia	Pamunkey Group
MESOZOIC:		
Cretaceous.		
Lower Cretaceous......	Patapsco	Potomac Group
Jurassic (?)		
Upper Jurassic (?)...	Arundel Patuxent	

The deposits of the Coastal Plain consist chiefly of unconsolidated beds of sand, gravel, clay and marl, which may be locally indurated by a cement either of iron oxide or carbonate of lime. These indurated ledges in the vicinity of Acquia creek and, in places, southward along the western margin representing the oldest formation of the Coastal Plain series, have afforded sandstone suitable for building purposes. The beds strike in general from north to south, although some variation occurs, with a low but variable easterly dip. Although not actually horizontal, except locally, the beds generally appear so in any given section, because of this relatively low dip. In age, the Coastal Plain beds range from Lower Cretaceous to Quaternary.

The broad and deep estuary of the Chesapeake Bay, which crosses the Coastal Plain region, finds an outlet seaward between the capes, Charles and Henry. This sheet of water affords unparalleled transportation facilities, and its principal tributaries, the Potomac, Rappahannock, York, and James rivers, give access to vessels as far westward as the Piedmont border—the "fall-line."

The Piedmont Plateau Province

The Piedmont Plateau province lies between the Coastal Plain and the Appalachian Mountains. It extends from the eastern slope of the Blue Ridge eastward to the western margin of the Coastal Plain, and it widens southward (map, figure 1, page 7). Its width increases from about 40 miles in the northern portion along the Potomac river to nearly 175 miles along the Virginia-Carolina boundary. The nearly horizontal and unconsolidated sediments of the Coastal Plain lie across the bevelled edges of the highly crumpled crystalline rocks of the Piedmont, presenting such marked stratigraphic and lithologic contrast that the geologic boundary between the two provinces is sharply defined. The transition on the west is less sudden and well marked.

The Piedmont province contains a greater variety of mineral resources than either of the other two provinces. In general, the surface of the Plateau has a gentle southeastward slope from an average altitude of 1,000 feet along the western margin to from 200 to 400 feet on the east, where the plateau rocks pass beneath the Coastal Plain sediments. The western border of the region is an irregular one, marking the change to the steeper slopes of the Blue Ridge and its outliers. The topography of the plateau is much older and more varied, and its geology more complex than that of the Coastal Plain. Its topography is that of a more or less smooth, broadly rolling or undulating upland of moderate elevation, into which the streams have rather deeply sunk their channels. Scattering hills and ridges—partially reduced masses—rise in some cases several hundred feet above the general level of the upland surface of the Plateau. Below the upland surface, deep and narrow gorges have been carved by the streams.

The drainage of the region is to the southeast into the Atlantic waters, and the major streams which traverse the Plateau are the Potomac, Rappahannock, James, and Roanoke rivers. All of these have their sources without the area, and, with the exception of the Rappahannock river, they rise west of the Blue Ridge. The smaller streams rise within the area and lie between the larger rivers, draining either into the latter or directly into the Chesapeake Bay. These streams usually flow in more or less deep rocky gorges, and have rapid currents as far as the eastern border of the Piedmont Plateau, where they debauch on to the Coastal Plain.

Lack of systematic study of the Virginia Piedmont region forbids more than a general description of its geology at this time. The rocks composing the region are the oldest in the State and, excepting the areas of Newark (Triassic) rocks, they are all crystalline. They comprise both sedimentary and igneous masses so greatly altered from metamorphism, chiefly through pressure and recrystallization, that many of them bear but slight resemblance to the original rocks. The metamorphism has induced secondary foliation into the rocks by arranging the mineral constituents along roughly parallel lines or planes; the foliation of which, in many cases, bears little or no relation to the original bedding planes in many of the sedimentary rocks.

The Plateau region is made up of a complex of schists, gneisses, and granites, with, in places, areas of slate, quartzite, and limestone. This complex is further intersected by intrusions of basic eruptive rocks belonging, so far as they have been studied, to the diabasic, dioritic, and gabbroic types. Over parts of the eastern and central portions of the region are areas of altered volcano-sedimentary rocks which extend southwestward into North Carolina.

Over the eastern, northern, central, and southern parts of the Piedmont are areas of Newark (Triassic) shale, sandstone, and conglomerate, and, in some of the areas, impure thin beds of limestone. There are seven areas of Newark rocks included within the limits of the Virginia Piedmont region. The northern, southern, and eastern areas of these rocks are quite extensive.

The rocks of the Plateau region have a general southeast dip, which varies within rather wide limits, usually between 20° and 70° and, in cases, steeper, sometimes almost or quite vertical. In general, they strike approximately northeast and southwest. Variations, however, in both dip and strike are frequent over the region.

The age relations of the rocks of the region are largely unknown. Excepting the areas of Newark (Triassic) rocks, the crystalline rocks were regarded as Archean by the older geologists, and they were so mapped by Professor Rogers. More recent studies, however, based in part on fossil evidence, reveal the fact that a part of them are as late as Ordovician in age.

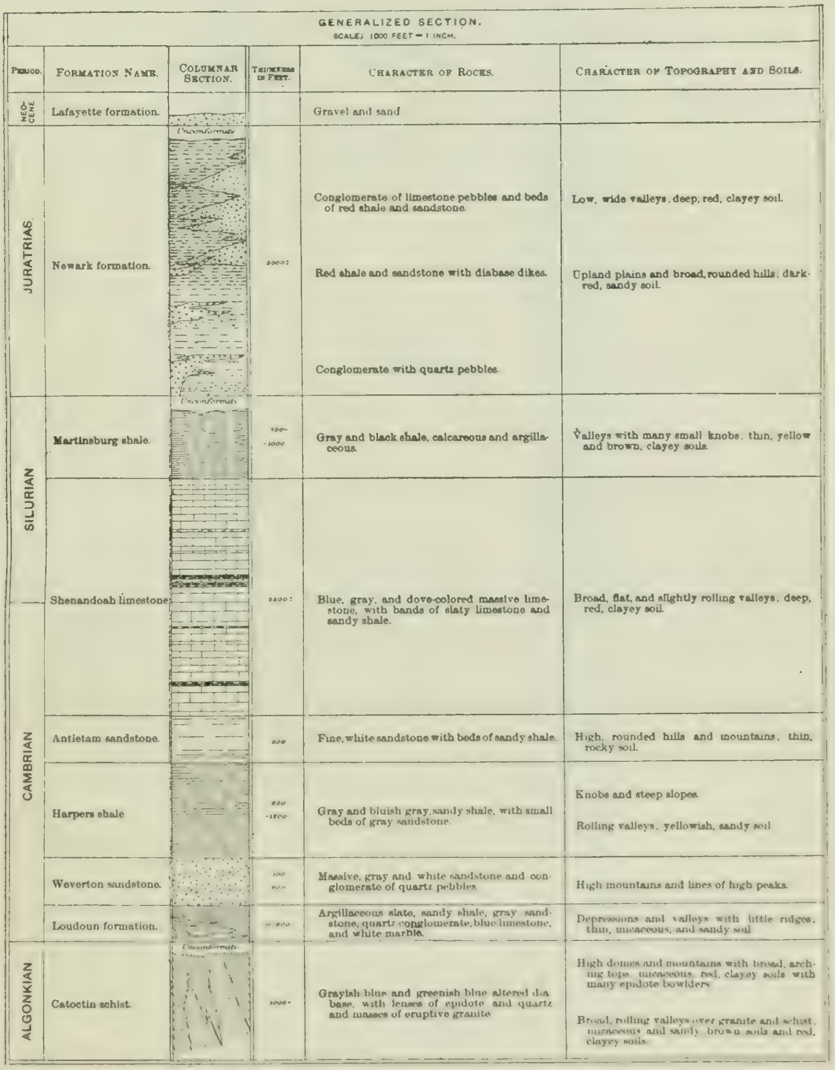
The Appalachian Mountains Province

The Appalachian Mountains province embraces the western portion of the State. Its eastern boundary, the southeastern slope of the Blue Ridge, forms in places not a gradual transition but an abrupt change from plateau to mountain conditions, and is reasonably well defined. In other places, the change is not so abrupt and the boundary is less well defined. The western limits of the province are artificially drawn in the western boundary of the State. This province, like the Piedmont Plateau and Coastal Plain, extends northeast and southwest far beyond the limits of Virginia.

The topography of the Appalachian province is varied and picturesque. Three sub-divisions of the province are recognized which, named from east to west, are: (1) The Blue Ridge; (2) the Great Valley; and (3) the Alleghany Ridges. The limits of these subdivisions are indicated on the map, figure 1, page 7.

The Blue Ridge, which forms the eastern boundary of the Appalachian province, maintains an uneven and knobby crest entirely across the State, in a northeast-southwest direction, and has an average elevation of not less than 2,000 feet above tide-level. At Harper's Ferry, the altitude of the Blue Ridge above tide is less than 1,000 feet, but southward through Virginia the ridge becomes higher and broader, and opposite Luray, Stony Man (4,031 feet) and Hawks Bill (4,066 feet) are its greatest elevations north of North Carolina.

The Blue Ridge is composed largely of pre-Cambrian rocks, represented in part, at least, by various igneous types, but sandstones and shales of Cambrian age are exposed along the western slope. It is a natural dividing line between the Paleozoic sediments comprising sandstones, limestones, and shales on the west, and the pre-Paleozoic and other rocks on the east. Figure 2, adopted from the Harper's Ferry folio of the United States Geological Survey, is a generalized section of a part of the Appalachian province in northern Virginia and southern Maryland, including a portion of the Blue Ridge.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GENERALIZED SECTION.
SCALE: 1000 FEET = 1 INCH.

PERIOD.	FORMATION NAME.	COLUMNAR SECTION.	THICKNESS IN FEET.	CHARACTER OF ROCKS.	CHARACTER OF TOPOGRAPHY AND SOILS.
NEOCENE	Lafayette formation.			Gravel and sand	
JURATRIAS	Newark formation.		3000±	Conglomerate of limestone pebbles and beds of red shale and sandstone. Red shale and sandstone with diabase dikes. Conglomerate with quartz pebbles.	Low, wide valleys, deep, red, clayey soil. Upland plains and broad, rounded hills, dark-red, sandy soil.
SILURIAN	Martinsburg shale.		700-1000	Gray and black shale, calcareous and argillaceous.	Valleys with many small knobs, thin, yellow and brown, clayey soils.
CAMBRIAN	Shenandoah limestone		2600±	Blue, gray, and dove-colored massive limestone, with bands of slaty limestone and sandy shale.	Broad, flat, and slightly rolling valleys, deep, red, clayey soil.
	Antietam sandstone.		500	Fine, white sandstone with beds of sandy shale.	High, rounded hills and mountains, thin, rocky soil.
	Harpers shale		800-1200	Gray and bluish gray, sandy shale, with small beds of gray sandstone.	Knobs and steep slopes. Rolling valleys, yellowish, sandy soil
	Weverton sandstone.		100-400	Massive, gray and white sandstone and conglomerate of quartz pebbles.	High mountains and lines of high peaks.
	Loudoun formation.		0-800	Argillaceous slate, sandy shale, gray sandstone, quartz conglomerate, blue limestone, and white marble.	Depressions and valleys with little ridges, thin, micaceous, and sandy soil
ALGONKIAN	Catoctin schist.		1000+	Grayish blue and greenish blue altered diabase, with lenses of epidote and quartz and masses of eruptive granite	High domes and mountains with broad, arching tops, micaceous, red, clayey soils with many epidote bowlders Broad, rolling valleys over granite and schist, micaceous and sandy brown soils and red, clayey soils.

Fig. 2.—Generalized section of area covered by the Harper's Ferry folio, U. S. Geol. Survey. (After A. Keith.)

The James and Roanoke rivers flow eastward through the Blue Ridge from the Alleghany Ridges, while the New river heads east of the Blue Ridge in North Carolina and flows northwest in Virginia across the Blue Ridge, the Alleghany Ridges, and the Alleghany Front, into the Ohio.

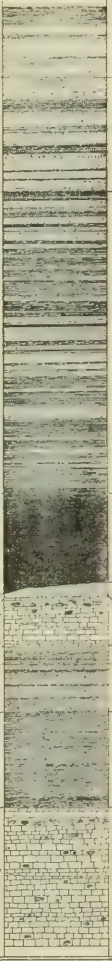
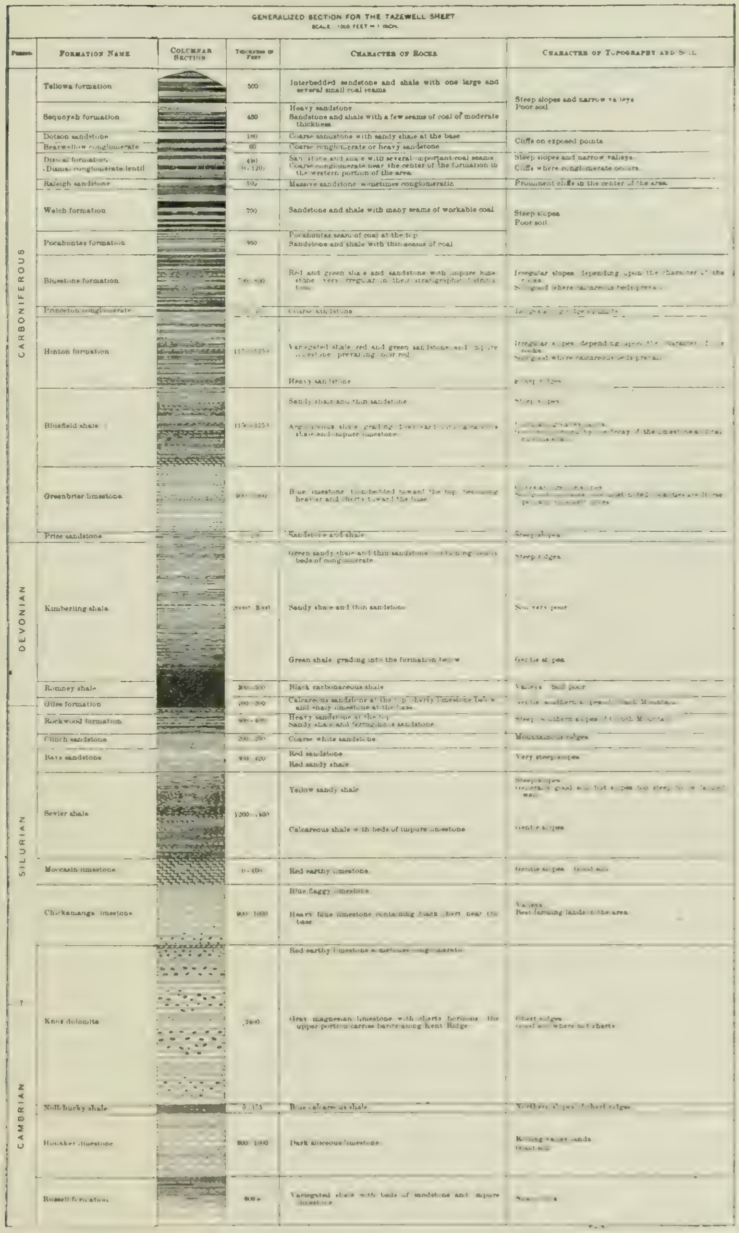
PERIOD.	FORMATION NAME.	COLUMNAR SECTION.	THICKNESS IN FEET	CHARACTER OF ROCKS.	CHARACTER OF TOPOGRAPHY AND SOILS.
CARB.	Pocono sandstone.		700+	Shale Coarse sandstone of light color, with sandy shale and thin coal beds.	Sharp ridges, with thin, sandy and rocky soils
DEVONIAN	Hampshire formation.		1000–1400	Thinly bedded, gray and reddish sandstone, with more-massive beds of fine-grained sandstone, all inter bedded with thin layers of shale.	High mountains, with thin, sandy soils
	Jennings formation.		2800–3400	Shales, varying from olive color to buff, interstratified with massive, mainly fine-grained sandstone.	Mountain slopes and moderately high ridges, with thin, sandy soils
	Romney shale		600–1000	Dark shale, black below	Wide valleys and low, rounded ridges. Thin soils, usually clayey. The valleys usually contain alluvial deposits of varying width
SILURIAN	Monterey sandstone.		0–300	Sandstone, in part calcareous	Knobs and ridges along the base of higher hills
	Lewistown limestone.		300–500	Cherty limestone Pure limestone.	Knobby ridges and elevated valleys. Thin but rich soils.
	Rockwood formation		150–200	Gray quartzite Sandy shale	Mountain slopes, overplaced by sandy soils
	Massanutten sandstone		500–600	Reddish sandstone Gray quartzite Red and gray sandstones.	High rocky ridges, with thin, sandy soils
	Martinsburg shale		800–1400	Gray shale, with sandy beds above and calcareous beds below	Low, rounded hills in the Appalachian Valley, and the eastern slope of Little North Mountain. Thin, sandy clay-soils
	Shenandoah limestone.		1500 +	Massive fossiliferous limestone Cherty limestone. Dolomitic (magnesian) limestone, varying from light gray to dark gray.	Moderately steep ridges in the Appalachian Valley The undulating surface of the Appalachian Valley, with clay-soils of variable depth.

Fig. 3.—Generalized section of area covered by the Staunton folio, U. S. Geol. Survey. (After N. H. Darton.)



GENERALIZED SECTION FOR THE TAZEWELL SHEET

SCALE 1000 FEET = 1 INCH

Period	Formation Name	Thickness in Feet	Character of Rocks	Character of Topography and Soil
CARBONIFEROUS	Tellowa formation	500	Interbedded sandstone and shale with one large and several small coal seams	Steep slopes and narrow valleys Poor soil
	Sequoyah formation	450	Heavy sandstone Sandstone and shale with a few seams of coal of moderate thickness	
	Dotson sandstone	180	Coarse sandstone with sandy shale at the base	Cliffs on exposed points
	Bearwallow conglomerate	60	Coarse conglomerate or heavy sandstone	
	Dismal formation (Dismal conglomerate lentil)	490 (0-120)	Sandstone and shale with several important coal seams Coarse conglomerate near the center of the formation in the western portion of the area	Steep slopes and narrow valleys Cliffs where conglomerate occurs
	Raleigh sandstone	100	Massive sandstone, sometimes conglomeratic	Prominent cliffs in the center of the area
	Welch formation	700	Sandstone and shale with many seams of workable coal	Steep slopes Poor soil
	Pocahontas formation	950	Pocahontas seam of coal at the top Sandstone and shale with thin seams of coal	
	Bluestone formation	[illegible]	Red and green shale and sandstone with impure limestone; very irregular in their stratigraphic distribution	Irregular slopes, depending upon the character of the rocks Soil good where calcareous beds prevail
	Princeton conglomerate	[illegible]	Coarse sandstone	[illegible]
	Hinton formation	[illegible]	Variegated shale, red and green sandstone and impure limestone, prevailing color red Heavy sandstone	Irregular slopes depending upon the character of the rocks Soil good where calcareous beds prevail Sharp ridges
	Bluefield shale	[illegible]	Sandy shale and thin sandstone Argillaceous shale grading downward into calcareous shale and impure limestone	Steep slopes [illegible] decay of the limestone [illegible]
	Greenbrier limestone	[illegible]	Blue limestone, thin-bedded toward the top, becoming heavier and cherty toward the base	[illegible]
	Price sandstone	[illegible]	Sandstone and shale	Steep slopes
DEVONIAN	Kimberling shale	[illegible]	Green sandy shale and thin sandstone containing several beds of conglomerate Sandy shale and thin sandstone Green shale grading into the formation below	Steep ridges Soil very poor Gentle slopes
	Romney shale	300-500	Black carbonaceous shale	Valleys. Soil poor
SILURIAN	Giles formation	100-300	Calcareous sandstone at the top, cherty limestone below, and shaly limestone at the base	[illegible] southern slopes of [illegible] Mountain
	Rockwood formation	[illegible]	Heavy sandstone at the top Sandy shale and ferruginous sandstone	Steep southern slopes of [illegible] Mountain
	Clinch sandstone	[illegible]	Coarse white sandstone	Mountainous ridges
	Bays sandstone	[illegible]	Red sandstone Red sandy shale	Very steep slopes
	Sevier shale	1200-1400	Yellow sandy shale Calcareous shale with beds of impure limestone	Steep slopes Generally good soil but slopes too steep to be farmed well Gentle slopes
	Moccasin limestone	0-400	Red earthy limestone	Gentle slopes. Good soil
	Chickamauga limestone	800-1000	Blue flaggy limestone Heavy blue limestone containing black chert near the base	Valleys Best farming lands in the area
?	Knox dolomite	[illegible]	Red earthy limestone sometimes conglomeratic Gray magnesian limestone with cherty horizons; the upper portion carries barite along Kent Ridge	Chert ridges Good soil where not cherty
CAMBRIAN	Nolichucky shale	0-175	Blue calcareous shale	Northern slopes of chert ridges
	Honaker limestone	800-1000	Dark siliceous limestone	Rolling valley lands Good soil
	Russell formation	800+	Variegated shale with beds of sandstone and impure limestone	[illegible]

Fig. 4.—Generalized section of the area covered by the Tazewell folio, U. S. Geol. Survey. (After M. R. Campbell.)

The two most westerly sub-provinces, the Valley and the Alleghany Ridges, bounded by the two principal ranges, the Blue Ridge and the Alleghany Front, on the southeast and northwest, respectively, are here treated together under the Greater Valley Region. These two nearly parallel ranges are separated in Virginia by a distance varying from 75 to more than 100 miles. Considered broadly, the Greater Valley region is composed of narrow valleys and linear ridges arranged in more or less complex relations. Some of the ridges, rising to considerable elevations, are narrow, of even crestline, and of great length. Others are less persistent and have less regular crests, while others still, which make up the minor irregularities of the surface, such as the hills, knobs and lower ridges, are of lower elevations.

At Harper's Ferry on the Potomac, the Valley proper is less than 300 feet above tide, but it gradually rises southwestward until it reaches the height of 1,700 feet in southwest Virginia. It will average from 20 to 30 miles wide, and is higher along the western side next to the Alleghany Ridges than on the eastern side. The Alleghany Ridges vary in average elevation from 1,000 to 3,000 feet above tide. Many of the ridges exceed 3,000 feet in height, and Elliots Knob, 20 miles west of Staunton, has an elevation of 4,473 feet.

Ordinarily, the ridges are unsymmetrical, one slope being much steeper than the other. In some cases, the two slopes are more nearly equal, and, in cross-section, the ridge approaches that of symmetry.

The Greater Valley region is composed throughout of Paleozoic sediments, which range in age from Cambrian to Carboniferous. The principal rock-types include limestone, shale, and sandstone. Four generalized sections, adopted from the Geologic Folios of the United States Geological Survey, in the northern, central and southwestern portions of the Greater Valley region, are shown in figures 2, 3, 4, and 5. These include formation name, columnar section, thickness in feet, character of rocks, and character of topography and soil. The principal formations of the Greater Valley region of western Virginia, especially those of the Cambrian and Ordovician systems, are described in detail in Bulletin No. II-A of the Virginia Geological Survey.

The geologic formations of Appalachian Virginia, including Cambrian, Ordovician, and post-Ordovician formations, are given in tabular form below, pages 17, 18, and 19.

Table of Cambrian and Ordovician formations for Northwestern Virginia.[a]

Age	Name			Thickness (feet)	Character of Rock
Upper Ordovician (Cincinnatian)	Massanutten sandstone.		Tuscarora quartzite (Richmond or Silurian)	300 ±	Coarse conglomerate and quartzite.
			Juniata shales and sandstones (Lorraine).....	200 ±	Sandy, reddish shales and coarser sandstone.
	Martinsburg shale.		Upper (Eden) shale.....	500 ±	Gray and buff sandy shales.
			Middle (Utica) shale....	1000 ±	Dark gray or black fissile shale.
			Lower (Trenton) shale...	100 to 300	Calcareous drab shales in lower half; more argillaceous strata in upper part.
Middle Ordovician (Mohawkian)	Shenandoah Group.		Chambersburg limestone	400	More or less pure and argillaceous limestone and calcareous shales.
			Stones River limestone..	900 ±	Heavily bedded dove and dolomitic limestone with purer dove strata in upper part.
Lower Ordovician (Canadian)		Natural Bridge.	Beekmantown limestone.	2300	Finely laminated massive bluish-gray magnesian and purer limestone with sandy cherts and some shale.
Saratogan (Upper Cambrian)			Conococheague limestone.	1500 ±	Dark blue magnesian limestone with limestone conglomerate at the base.
Acadian (Middle Cambrian)			Elbrook limestone..	3000 ±	Blue-gray dolomitic limestone, with some cherty limestone and red shale.
			Wautaga shale.........	1250 ±	Reddish shales with mottled blue limestone and flaggy sandstone.
Georgian (Lower Cambrian)			Shady limestone........	1000 ±	White crystalline dolomite, gray magnesian limestone, with occasional beds of argillaceous limestone and shale.
			Antietam sandstone.....	500 ±	Firm white sandstone and sandy shales.
			Harpers shale..........	1000 ±	Bluish-gray sandy shales.
			Weverton sandstone....	100 to 900	Massive gray and white sandstone.
			Loudoun formation.	0 to 800	Slates, shales, sandstone, limestones, and conglomerates.
Algonkian (?)......			Catoctin schist.........	1000 ±	Grayish-blue and altered diabase with masses of eruptive granite.

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[a] Bassler, R. S., Virginia Geological Survey, Bulletin No. II-A, 1909.

Cambrian and Ordovician formations of Southwest Virginia.[a]

General Time Scale	Bristol Area	Walker Mt. Area	Clinch Mt. Area	Copper Creek Area	Powell Valley Area
Upper Ordovician		Clinch Bays Sevier	Clinch Bays Sevier	Clinch Bays Sevier	Clinch Bays (Lorraine) Sevier (Eden)
Middle Ordovician	Tellico Athens Stones River (often absent)	Moccasin Holston Athens Stones River	Moccasin Holston and associat'd strata	Moccasin Chickamauga	Chickamauga (Trenton) (Tyrone) (Stones River)
Lower Ordovician Saratogan (Upper Cambrian)	Knox	Knox	Knox	Knox	Knox
Acadian (Middle Cambrian)	Nolichucky Honaker	Nolichucky Honaker	Nolichucky Maryville Rogersville Rutledge	Nolichucky Maryville Rogersville Rutledge	
Georgian (Lower Cambrian)			Russell	Russell	

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[a] Bassler, R. S., Virginia Geological Survey, Bulletin No. II-A, 1909.

Table of Post-Ordovician Formations in Appalachian Virginia.[a]

Period.	Rogers		Northwestern and Central Western Virginia	Max. thickness in feet.	Southwestern Virginia (Northern half)	Max. thickness in feet.	Southwestern Virginia (Southern half)	Max. thickness in feet.
Pennsylvanian	No. XIII—Lower coal group				Tellowa sandstone, etc.	500		
					Sequoyah sandstone, etc.	450		
	No. XII—Great conglomerate				Dotson sandstone	180		
					Bearwallow conglomerate	60	Harlan sandstone	880
					Dismal sandstone, etc.	490	Wise sandstone, etc.	1260
					(Dismal conglomerate lentil)	120	Gladeville sandstone	120
					Raleigh sandstone	100	Norton sandstone, etc.	1300
					Welch sandstone, etc.	700	Lee conglomerate	1500
					Pocahontas sandstone, etc.	360		
Mississippian	No. XI	Greenbrier shale			Bluestone sandstone, etc.	800		
					Princeton conglomerate	40		
					Hinton sandstone, shale, etc.	1250		
					Bluefield shale	1250	Pennington shale	1100
		Greenbrier limestone			Greenbrier limestone	1000	Newman limestone	1000
	No. X—Montgomery grits		Pocono sandstone	700	Price sandstone	200	Price sandstone	300
Devonian	Nos. IX and VIII	Catskill Chemung	Hampshire sandstone	1800				
		Portage Genesee	Jennings shale and sandstone	3800	Kimberling sandy shale, etc.	3000	Grainger sandy shale	500
		Hamilton Marcellus			Romney black shale	500	Chattanooga black shale	1000
	Nos. VII and VI	Oriskany	Romney black shale	1300				
		Lower Helderberg	Monterey sandstone	300	Giles sandstone and cherty limestone	250	Hancock limestone	275
			Lewistown limestone	1050				
Silurian	No. V—Clinton		Lewisto'n shaly limestone		Giles shaly limestone			
			Rockwood sandstone, etc.	900	Rockwood sandstone, etc.		Rockwood sandstone, etc.	670
	No. IV—Medina		Massanutten sandstone:		Clinch sandstone		Clinch sandstone	250
			Cacapon member	630				
			Tuscarora member	300				

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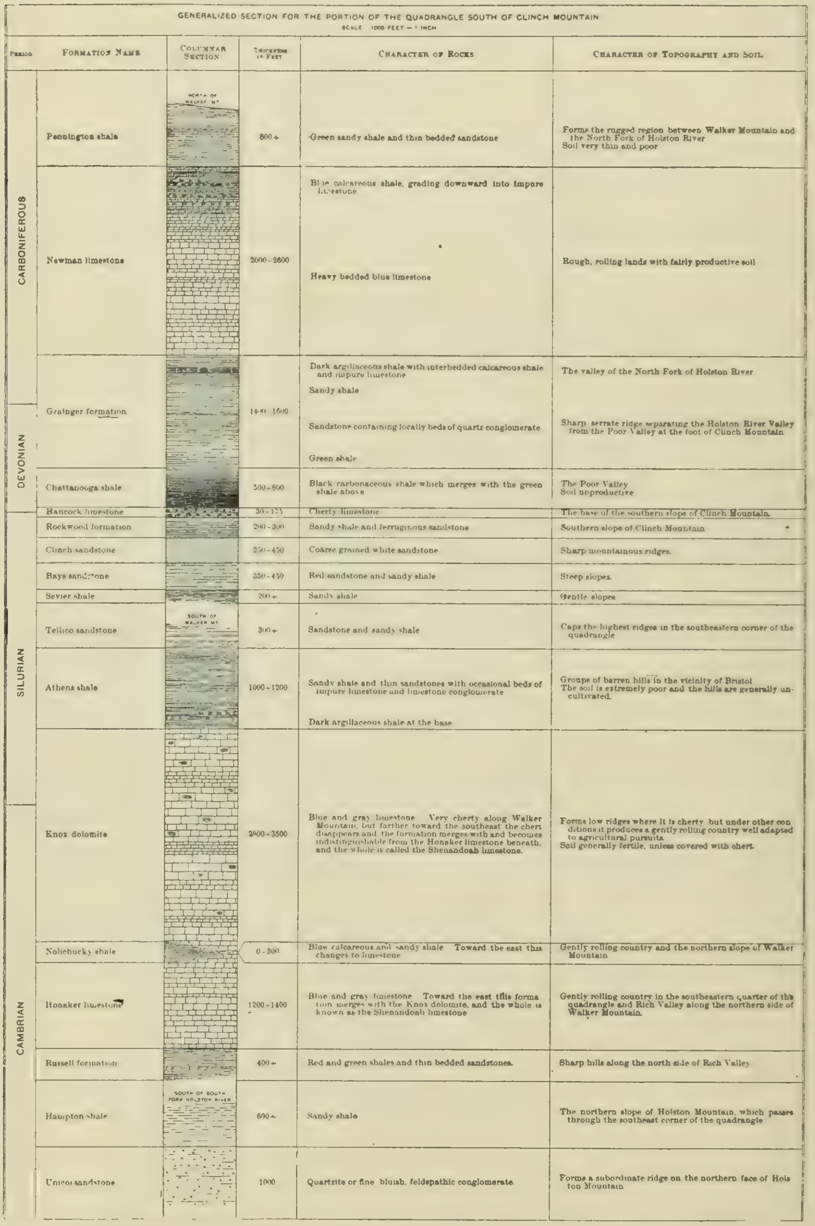
[a] Bassler, R. S., Virginia Geological Survey, Bulletin No. II-A, 1909.



GENERALIZED SECTION FOR THE PORTION OF THE QUADRANGLE SOUTH OF CLINCH MOUNTAIN

SCALE 1000 FEET = 1 INCH

Period	Formation Name	Columnar Section	Thickness in Feet	Character of Rocks	Character of Topography and Soil
CARBONIFEROUS	Pennington shale	NORTH OF WALKER MT	800 +	Green sandy shale and thin bedded sandstone	Forms the rugged region between Walker Mountain and the North Fork of Holston River Soil very thin and poor
	Newman limestone		2000 - 2600	Blue calcareous shale, grading downward into impure limestone Heavy bedded blue limestone	Rough, rolling lands with fairly productive soil
DEVONIAN	Grainger formation		1400 - 1600	Dark argillaceous shale with interbedded calcareous shale and impure limestone Sandy shale Sandstone containing locally beds of quartz conglomerate Green shale	The valley of the North Fork of Holston River Sharp serrate ridge separating the Holston River Valley from the Poor Valley at the foot of Clinch Mountain
	Chattanooga shale		500 - 800	Black carbonaceous shale which merges with the green shale above	The Poor Valley Soil unproductive
SILURIAN	Hancock limestone		30 - 175	Cherty limestone	The base of the southern slope of Clinch Mountain.
	Rockwood formation		200 - 300	Sandy shale and ferruginous sandstone	Southern slope of Clinch Mountain
	Clinch sandstone		250 - 450	Coarse grained white sandstone	Sharp mountainous ridges.
	Bays sandstone		350 - 450	Red sandstone and sandy shale	Steep slopes.
	Sevier shale		200 +	Sandy shale	Gentle slopes
	Tellico sandstone	SOUTH OF WALKER MT	300 +	Sandstone and sandy shale	Caps the highest ridges in the southeastern corner of the quadrangle
	Athens shale		1000 - 1200	Sandy shale and thin sandstones with occasional beds of impure limestone and limestone conglomerate Dark argillaceous shale at the base	Groups of barren hills in the vicinity of Bristol The soil is extremely poor and the hills are generally uncultivated.
CAMBRIAN	Knox dolomite		2800 - 3500	Blue and gray limestone Very cherty along Walker Mountain, but farther toward the southeast the chert disappears and the formation merges with and becomes indistinguishable from the Honaker limestone beneath, and the whole is called the Shenandoah limestone.	Forms low ridges where it is cherty but under other conditions it produces a gently rolling country well adapted to agricultural pursuits. Soil generally fertile, unless covered with chert.
	Nolichucky shale		0 - 300	Blue calcareous and sandy shale Toward the east this changes to limestone	Gently rolling country and the northern slope of Walker Mountain
	Honaker limestone		1200 - 1400	Blue and gray limestone Toward the east this formation merges with the Knox dolomite, and the whole is known as the Shenandoah limestone	Gently rolling country in the southeastern quarter of the quadrangle and Rich Valley along the northern side of Walker Mountain.
	Russell formation		400 +	Red and green shales and thin bedded sandstones.	Sharp hills along the north side of Rich Valley
	Hampton shale	SOUTH OF SOUTH FORK HOLSTON RIVER	600 +	Sandy shale	The northern slope of Holston Mountain, which passes through the southeast corner of the quadrangle
	Unicoi sandstone		1000	Quartzite or fine bluish, feldspathic conglomerate	Forms a subordinate ridge on the northern face of Holston Mountain

Fig. 5.—Generalized section for the portion of the area south of Clinch mountain covered by the Bristol folio, U. S. Geol. Survey. (After M. R. Campbell.)

The simple horizontal arrangement of the rocks composing the Greater Valley region into alternating hard and soft beds at the time of deposition, has been greatly complicated by folding and faulting. The present attitude of the beds indicates that in general they have been arched into great folds and troughs, whose axes extend, as a rule, in a northeast-southwest direction. Sufficient time has elapsed since the folding and faulting occurred for the rocks to be greatly eroded. The softer or less resistent rocks, like shale and limestone, were lowered more rapidly by erosion than the harder and more resistent rocks like sandstone, hence the former rocks are in general valley-making while the latter are ridge-forming. The formations are now exposed in long, narrow belts, the widths of which depend on the thickness of the formation and the angle of dip. As a result of the bending into arches and troughs of the beds, and of subsequent erosion, the edges of the formations form linear ridges and valleys, developing the well-known Appalachian type of topography. This dependence of topography on structure and lithologic character of the rocks is well illustrated in the present surface configuration of the Greater Valley region.

As indicated in the recent study of the Greater Valley region of Virginia, certain differences in the general geology of the region are shown, which have resulted in dividing the entire region in Virginia west of the Blue Ridge into three areas, designated as the northwestern, central-western, and southwestern areas. In each of these the geologic sequence differs to some extent, and the structure is progressively more complex southwestward. The differences in these three areas are discussed in Bulletin No. II-A of the Virginia Geological Survey.

Structurally, the southwestern Virginia area is more complex than either of the other two, by reason of great folds and overthrust faults. Study of the region shows that it is traversed in a northeast-southwest direction by not less than seven major faults, and by a number of minor ones. The major faults are, named in order from east to west: (1) The Holston and Iron Mountain fault; (2) the Walker Mountain fault; (3) the Saltville fault; (4) the Copper Creek fault; (5) the Hunter Valley fault; (6) the Wallen Valley fault; and (7) the Poor Valley fault. Structure section, figure 6, page 23, shows the relations of these faults to each other and to the folds. The mineral resources occurring in the region west of the Blue Ridge bear an intimate relation to the structure of the rocks.

EFFECTS OF WEATHERING AND EROSION

Through the various atmospheric or external agents grouped under the comprehensive term *weathering,* all land surfaces when exposed for a sufficient length of time are attacked and gradually lowered in elevation, not equally but unequally, some areas more rapidly than others, and some parts of the same area more rapidly than other parts. All conditions being equal, that area which has been continuously above water for the longest time has suffered the greatest effects from the atmospheric agents.

Accordingly, the surface rocks over all parts of Virginia show some effects from atmospheric action. Of the three major provinces of the State described above, the Coastal Plain, on account of its very recent geologic history, has suffered the least. The remaining two provinces, Piedmont Plateau and Appalachian Mountains, bear striking evidence over all their parts of profound decay and erosion, which have resulted in the removal of vast quantities of rock material. Just how much of their surface has been lowered, or what vertical thickness of material has been removed from these land areas and carried seaward, would probably be very difficult to say, but that it has been large can not be doubted. Because of its greater geologic age and the vast length of time it has been a land area, the Piedmont Plateau has probably suffered the removal of the greatest thickness of material, which contributed in part to the building of the Appalachian province on the northwest, and to the Coastal Plain province on the southeast.

Through this process of degeneration—weathering—which has been going on for a vast period of time, a mantle of varying thickness of decayed rock material overlies the still fresh or sound rock, except where the erosive action has not been too excessive and the slopes too steep for its accumulation. This residual material is loose and porous or incoherent, consisting usually of clay, sand and gravel, and on the immediate surface forms soil. On depth it passes by imperceptible gradation into the hard and fresh unaltered rock. The thickness of residual material varies from a few inches to 50, 60 and, in extreme cases, 100

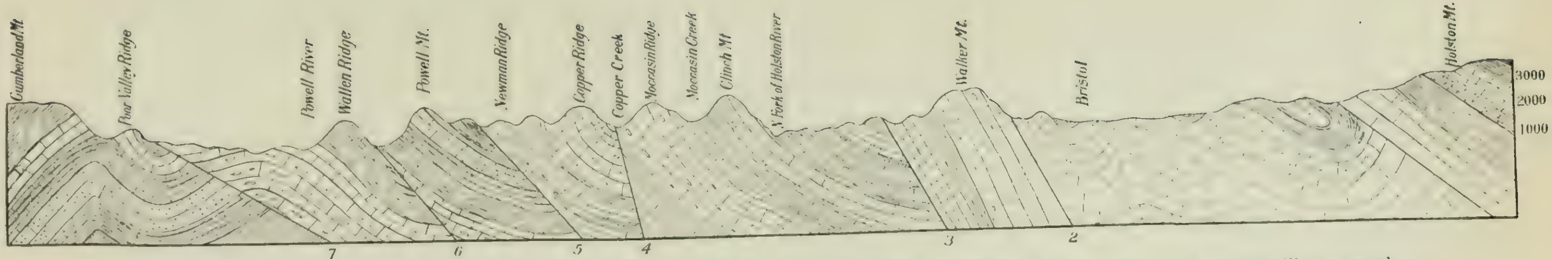


Fig. 6.—Structure section across southwest Virginia from Holston mountain west to Cumberland mountain. This section illustrates the blocks into which southwest Virginia is divided by major faults of the region. The length of the section has been greatly lessened and the height exaggerated. As a result, only the general geologic structure of each block could be shown. 1. Fault along western edge of Holston mountain; 2. Walker mountain fault; 3. Saltville fault; 4. Copper creek fault; 5. Hunter valley fault; 6. Wallen valley fault; 7. Poor valley fault.

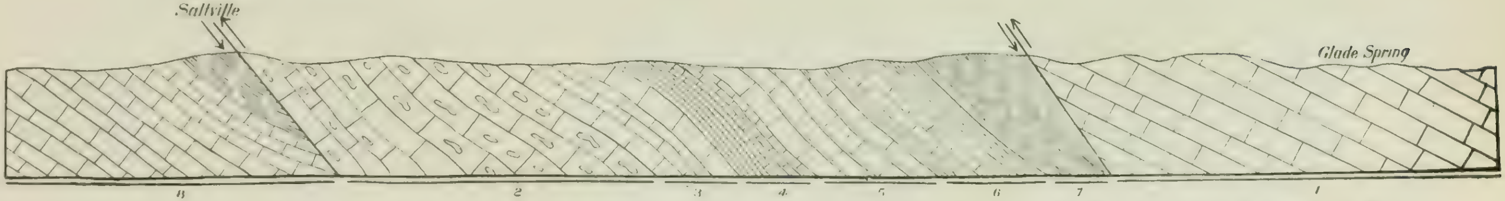


Fig. 7. Structure section along railroad from Glade Spring to Saltville. 1. Cambrian limestone; 2. Knox dolomite; 3. Stones River limestone; 4. Athens shales; 5. Holston formation; 6. Moccasin limestone; 7. Sevier shale; 8. Carboniferous limestone and shale.

feet. Over many parts of the State, so profound is the decay that exposures of the hard rock are rare, except along the stream courses where the mantle has been cut through by erosion.

This process of rock decay is of very great economic importance. Apart from the consideration of the great variety of soils resulting therefrom, which form perhaps Virginia's most valuable asset, workable ore deposits have been formed by it from sparsely disseminated and non-workable mineral matter in the original rocks. This is best illustrated in the manganese deposits, in a part of the iron and zinc deposits, and in other ore deposits of the State.

DIVERSITY OF RESOURCES

There is probably no state in the Union, of the same area as Virginia, that can show a greater diversity in geologic resources. This is confirmed by the actual exploitation thus far made, and it might be naturally inferred from the position which the State occupies with reference to disturbed and undisturbed areas as described above. As indicated above and from an examination of the geologic map, the State stretches from the Atlantic coast westward nearly entirely across the Appalachian Mountain system. Within this area are found rocks ranging in age from pre-Cambrian to Recent, and representing all the principal divisions of geologic time. Equally as great a variety of rock-types, both sedimentary and igneous, of structure which characterizes both profoundly disturbed and undisturbed rock masses, and of topography, is shown.

The mineral products that have been mined and quarried in Virginia are discussed in this bulletin in the following order: Iron ores, manganese ores, gold and silver, copper, lead and zinc, tin, nickel and cobalt, coal and coke, clay and clay products, lime and cement, sand and gravel, sand-lime brick, stone (granite, marble, limestone, sandstone, slate, crushed stone, and furnace flux), abrasive materials (corundum, emery, and millstones), silica (quartz, chert, and diatomaceous earth), mica, feldspar, asbestos, talc and soapstone, barytes, gypsum, salt, mineral paints, marl, pyrite and pyrrhotite, arsenic, phosphate, graphite, rutile (titanium), monazite, mineral waters, and precious stones (quartz, garnet, allanite, kyanite, fluorite, feldspar, microlite, apatite, beryl, columbite, and helvite).

IRON ORES AND PIG IRON

Mining of iron ore in Virginia in 1609 by the Jamestown colonists was the first iron ore mined in the United States.[a] The successful extraction of the metal from this ore led to the erection of the first iron works in the United States, which were located on Falling creek about seven miles south of Richmond, between the years 1619 and 1622. The works were destroyed in the Indian massacre of 1622 before they had been operated. The building of the Germania (Rappahannock) furnace about 1714, by Governor Spotswood, in Spottsylvania county, marked the first successful iron industry in the South. By 1781, a total of ten furnaces had been built, seven of which were located in the Piedmont region (two in Spottsylvania county, one each in Albemarle and Stafford counties, and three south of the James river), and three in the Appalachian region (two in Wythe county and one in Frederick county). At the close of the year 1908, there was a total of 26 blast furnaces in the State, only 10 of which were in blast, because of the prevailing depressed conditions in the money market throughout the country.

The present commercial deposits of iron ore in Virginia are confined to the Piedmont and Appalachian regions. The iron ores of the Piedmont region occur in metamorphic crystalline rocks of unknown age, probably pre-Cambrian in large part; those of the Appalachian region occur in sedimentary rocks of Paleozoic age, or the residual material derived from them.

The iron minerals used as ores of the metal in the State are, chemically, oxides, of which there are three important types, limonite (brown hematite), hematite, and magnetite. Of these, the brown hematite has been and is the principal source of the metal, as indicated in the table on page 33. The sulphides and carbonate, especially the former, occur in many places, but they do not form as yet an important source of the metal.

The iron ores of Virginia may be classified as follows:[b]

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[a] Holden, R. J. Chapter on "Iron" in Mineral Resources of Virginia, 1907, p. 402.

[b] Harder, E. C. Bulletin 380, U. S. Geological Survey, 1909, pp. 216–217. The sulphide types of iron ores are omitted from the scheme of classification as they have not yet contributed to the production of metal in Virginia, but are utilized in acid making, and are treated under Pyrite and Pyrrhotite on pages 121-126.

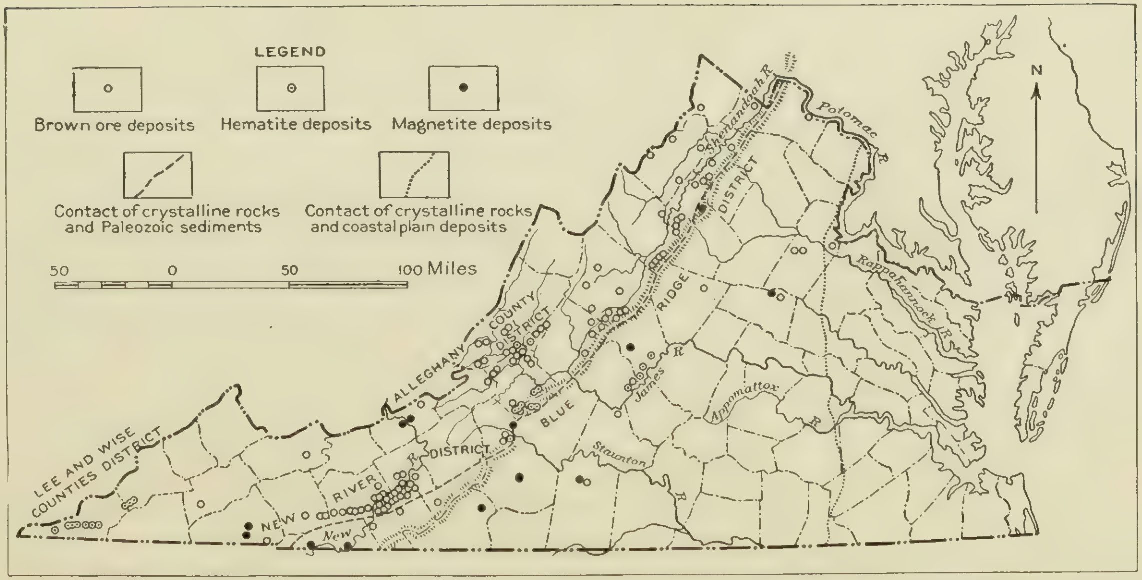

Fig. 8.—Map showing the distribution of various classes of iron ores in Virginia. (After E. C. Harder.)

PIEDMONT REGION:

1. Hematite. Specular hematite associated with magnetite in the James river valley.
2. Brown ore. Gossan ore forming a capping of pyrrhotite deposits in southwestern Virginia, and pyrite deposits in northern and central Virginia.
3. Magnetite. Associated with gneisses, schists, and crystalline limestones, in central and southwestern Virginia, and with basic intrusions in the Blue Ridge.

APPALACHIAN REGION:

1. Hematite.
    - (a) Siliceous specular hematite interbedded with lower Cambrian shale and quartzite in the Blue Ridge.
    - (b) Fossil (red) hematite interbedded with shale and sandstone of Clinton (Rockwood) formation in western and southwestern Virginia.
2. Brown ore.
    - (a) "Mountain" ores of the Blue Ridge and of the New River district, associated with lower Cambrian quartzite and with residual material above it derived from the quartzite and from the overlying formations.
    - (b) "Valley" ores associated with residual material of the Shady limestone in the New River district. A few deposits of this nature occur with other limestones of the Shenandoah group along the Blue Ridge.
    - (c) Oriskany ores replacing the Lewistown limestone directly under the "Monterey" (Oriskany) sandstone in the western part of the Appalachian region.
3. Magnetite. Magnetite and hematite associated with limonite and iron carbonate in the upper part of the Shenandoah group locally in southwestern Virginia.
4. Iron carbonate. Iron carbonate occurring with limestone magnetite in the upper part of the Shenandoah group locally in southwestern Virginia, and as ironstone concretions in the Martinsburg and Romney shales.

In recent years, the iron ores of the Piedmont region have contributed only a very minor part of the total production of the ores in the State, though small quantities of magnetite and limonite (brown ore) are produced annually from this region.

Magnetite deposits, usually having the form of lenticular beds or elongated pods and interlaminated with gneisses, schists and, in places, limestones, are widely distributed through the Piedmont region. They occur in Albemarle, Amherst, Appomattox, Buckingham, Fluvanna, Franklin, Grayson, Louisa, Nelson, Patrick, Henry, and Pittsylvania counties. The James river valley area below Lynchburg was a principal iron-producing district in the State about a hundred years ago, and was exploited again about 1880. In recent years, the magnetite ore at Pittsville in Pittsylvania county has been the most extensively mined in the Piedmont region. The ore body has a thickness of 12 feet and occurs between crystalline limestone and mica schist. Magnetite has been mined near Rocky Mount, in Franklin county, and west of Goblintown creek in Patrick county. The magnetite deposits vary in thickness up to 30 feet and more, and they show much irregularity (pinching and swelling) on both the strike and the dip. They vary greatly in composition, from bodies containing practically all iron ore to those made up largely of gangue minerals with but little ore. They include both non-titaniferous and titaniferous types.

Brown (gossan) ore, resulting from the oxidation of pyrite and pyrrhotite above groundwater level, has wide distribution through the Piedmont region. It occurs capping the pyrite bodies in metamorphic crystalline schists of unknown age, of Buckingham, Louisa, Prince William, Spottsylvania, and Stafford counties, and formed the basis for the first iron industry in Virginia; but it has not been mined in recent years. Similar ore occurs in Carroll, Floyd, Franklin, and Grayson counties, forming the capping of pyrrhotite deposits in metamorphic crystalline schists.

The "Great Gossan Lead" of Carroll-Floyd-Grayson counties, traceable for a distance of 18 miles, is the most extensive one of the gossan leads. It is quite variable in width, ranging from a few feet up to more than 150 feet. The gossan consists of light brown or yellow limonite, which extends to a depth of from 10 to 60 feet, and has been mined in many places.

The brown iron ores of the Appalachian region, which include the "mountain," valley or limestone, and Oriskany ores, are commercially the most important ores in Virginia. The specular hematites of the Blue Ridge are second in importance, the Clinton fossil ores third, and the remaining types are of minor importance. These types of ores are briefly described below.

Specular hematite occurs in workable quantity along the Blue Ridge in Bedford, Botetourt, and Roanoke counties. It occurs interbedded with lower Cambrian quartzite and shale, and is believed to be sedimentary in origin. The ore bed is of variable thickness and has been worked at eight localities, as follows:[a] "The Arcadia and Wood mines, about 4 miles southeast of Buchanan; the Ironville and Dewey mines, near Montvale; the Lemon, Grubb-Specular and Edith mines, about 3 miles northwest of Blue Ridge Springs; and the Griffin-Specular mine, about 5 miles south of Roanoke. Of these, the Arcadia, Wood, Dewey, and Edith mines are at present in operation." The ore is a very siliceous dark-red hematite, in which the iron content ranges from less than 35 per cent. to 45 per cent., and the silica content from 30 to 40 per cent.[a]

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[a] Harder, E. C. Bulletin 380, U. S. Geological Survey, 1909, p. 225.

Fossil hematite, interbedded with shale and sandstone of the Clinton (Rockwood) formation of the Silurian system, occurs in workable quantity in Alleghany, Lee, and Wise counties. In Alleghany county, fossil ore has been mined on the southeast slope of Horse mountain, 3 miles southeast of Low Moor, and in the bluff northeast of Jackson river at Iron Gate. Only one workable bed of ore is known, which averages less than two feet in thickness. The ore mined is of the soft variety from which the calcium carbonate has been removed by surface waters, and it carries 46 to 57 per cent. of metallic iron. According to Hayes,[b] nearly 90,000 tons of fossil ore were shipped in 1907 from mines in the Alleghany county district.

In the Lee-Wise counties district of southwest Virginia, fossil hematite ore is mined south of Big Stone Gap on Wallen Ridge, and in Powell Valley, and southwest of Pennington Gap along Poor Valley ridge. The Yeary, Irondale, Keystone, and Oreton mines have been opened south of Big Stone Gap, and the Pennington, Lavine, Ben Hur, Truro, Noes Siding, Grabill, Boones Path, and Ewing mines are opened along Poor Valley ridge. In the southwest Virginia district there are three ore beds which have been mined, ranging in thickness from 6 inches to 2.5 feet. The ores mined are chiefly of the soft variety, and are of lower grade than those of the Alleghany county district.

The "mountain" brown ores, so called because of their occurrence along the flanks or at the base of a sandstone or quartzite ridge, extend along the west slope of the Blue Ridge from near Front Royal, in Warren county, to a point south of Roanoke, and along the east side of the New River-Cripple Creek district, in Pulaski county, and along and near to the Wythe-Carroll counties boundary. The ore deposits are associated with Cambrian quartzite or its residual material, usually the latter, show great variation in form and texture, and range in iron content from 35 to 50 per cent. and in silica content from 10 to 30 per cent., with usually high manganese and phosphorus. They are of lower grade than the valley or limestone brown ores, and are regarded as concentrations by meteoric water, the iron having been derived largely if not entirely from the overlying shale and limestone formations.

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[a] Ibid., pp. 227 and 228.

[b] Hayes, C. W. Bulletin 394, U. S. Geological Survey, 1909, p. 88.

The valley or limestone brown ores are distributed at intervals throughout the Valley region west of the Blue Ridge, in association with the residual clays derived from the limestone by processes of decay. The principal occurrence of these ores is in the New River-Cripple Creek district of Wythe and Pulaski counties, in residual clays derived from the Shady (lower member of the Shenandoah group) limestone. A large number of mines have been operated in this district.

In the northern and central Valley region the limestone brown ores are not so abundant, there being less than a dozen deposits that have been worked between Roanoke and the Maryland boundary. The ores of this region, called the Blue Ridge belt, occur in residual clays derived from the Natural Bridge limestone.

The ore is disseminated through the residual clay in varying concentrations ranging from large porous masses down to pellets the size of a pea. The proportion of clay to ore in the workable deposits varies considerably, usually from 5 to 1 to 25 to 1.[a] The ores are usually richer than the "mountain" ores ranging in iron content from 40 to 55 per cent., and in silica content from 5 to 20 per cent., with usually less than 1 per cent. of manganese and enough phosphorus to be classed as a non-Bessemer ore.

The valley or limestone brown ores are residual deposits, the iron of which was originally disseminated through the rocks and, under favorable conditions, has been concentrated during the process of weathering and erosion.

The Oriskany brown ores are the most important of the iron ores mined at present in Virginia. The principal district of Oriskany ores includes the counties of Alleghany, Botetourt, and Craig, from which nearly all the ore mined of this type is produced. Minor deposits occur on Draper mountain, in Pulaski and Wythe counties; on Peters mountain, Giles county; in the Buffalo Gap area, Augusta county; in Massanutten mountain, Shenandoah county; and on North mountain, in Shenandoah and Frederick counties.[a]

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[a] Harder, E. C. Bulletin 380, U. S. Geological Survey, 1909, p. 244.

These ores are limited to a definite horizon, in the Lewistown (Helderbergian) limestone, immediately below the Monterey (Oriskany) sandstone. They represent replacements of the upper portion of the limestone. The ore was derived from the overlying Devonian black shales by meteoric waters. Where the shales were of sufficient thickness and the underlying Monterey sandstone sufficiently thin and fractured, the iron-bearing solutions penetrated into the underlying limestone and, under favorable conditions, replaced the calcium carbonate by iron-oxide, forming the ore bodies. Harder gives the following typical section of the Monterey and Lewistown formations at the principal ore deposits in Alleghany county and vicinity:[b]

	Feet
Romney shale:	
Black shale	600+
Grayish blue clay	1–5
Monterey (Oriskany) sandstone, dark-colored and iron-stained	0–20
Lewistown limestone:	
Pure heavy-bedded limestone	10–60
Cherty limestone	20–60
Limestone and sandstone	200+
Clinton (Rockwood) formation	150+

The ore deposits are continuous for considerable distances along the strike with great variations in thickness of the ore bodies shown, ranging up to 75 feet with a probable average of 15 to 25 feet. The ore, usually fairly solid but frequently porous with the cavities containing clay, ranges between 35 and 50 per cent. of metallic iron. They are usually high in silica and manganese, and, in this particular, they resemble the "mountain" ores.

The principal Oriskany brown ore mines[c] in the State are Liberty and Van Buren Furnace mines, in Shenandoah county; the Buffalo Gap and Ferrol mines, in Augusta county; the Victoria and Longdale mines, north of Longdale, Alleghany county; the Dolly Ann, Iron Mountain, and Stack mines, near Covington, Alleghany county; the

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[a] Harder, E. C. Ibid. p. 246.

[b] Op. cit., p. 247.

[c] Op. cit., p. 248.

Low Moor and Rich Patch mines, near Low Moor, Alleghany county; the Jordan mines, on Potts creek, Alleghany county; the Callie, Wilton, and Circle mines, near Glen Wilton, Botetourt county; the Oriskany and Fenwick mines, in Botetourt and Craig counties, near Oriskany; the Gala mines, near Dagger Spring, Botetourt county; the Clayton and Peak Knob mines, near Pulaski, Pulaski county; and the Locust Hill mine, near Max Meadows, Wythe county.

The remaining types of Appalachian iron ores in Virginia, including the limestone magnetite and iron carbonate ores, are of minor importance. The principal deposits of the limestone magnetite ores, so far known, occur near Big Sandy Junction, in Giles county, and near Abingdon, in Washington county, with smaller deposits elsewhere in southwest Virginia. Iron carbonate is reported in minable quantity from only one locality, namely, near Abingdon, in Washington county, in association with limestone magnetite ore.[a]

The iron ores of the State are under investigation by the Virginia Geological Survey, after the completion of which a detailed report will be published.

The iron ore mining industry in Virginia suffered a decided falling off last year, and, excepting the year 1904, it is the first time in many years the production has been as small. The production of iron ores in 1908 amounted to 692,223 long tons, valued at $1,465,691, as against 786,856 long tons, valued at $1,538,920, in 1907. This was a decrease from 1907 of 94,633 long tons or 12.03 per cent. in quantity, and $73,229 or 4.75 per cent. in value. The average price per ton of iron ore in 1908 was $2.12 as compared with $1.96 in 1907. Forty-eight operators contributed to the production in 1908, distributed among 13 counties as follows: Alleghany, Augusta, Botetourt, Carroll, Craig, Lee, Pittsylvania, Pulaski, Roanoke, Rockbridge, Warren, Washington, and Wythe.

Important developments have been in progress in Catawba valley and in Potts creek valley, but unfortunately little can be published in this report concerning these developments further than to state that both areas will probably become important producing areas in the very near future.

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[a] Holden, R. J. Chapter on "Iron" in Mineral Resources of Virginia, 1907, p. 462.

There is given in the table below the total production of iron ore in Virginia by varieties. It will be observed that brown hematite is vastly the most important, producing at present more than 95 per cent. of the total. The next in order of importance is hematite, which contributed, in 1908, only 3.26 per cent. of the total production, while magnetite for the same year amounted to less than 1 per cent.

Production of Iron Ore in Virginia, by Varieties, 1900-1908, in long tons.

Year	Brown hematite	Red hematite	Magnetite	Total quantity	Total value
1900[a]	918,157	3,664	....	921,821	$1,489,318
1901[a]	910,214	13,156	2,024	925,394	1,466,423
1902[a]	953,128	31,677	3,153	987,958	1,667,456
1903[a]	764,948	31,609	4,604	801,161	1,432,624
1904[a]	528,853	17,952	3,448	550,253	951,478
1905	704,470	35,357	518	740,345	1,256,428
1906	735,204	92,257	620	828,081	1,579,817
1907	696,518	89,867	471	786,856	1,538,920
1908	626,910	64,323	990	692,223	1,465,691

[a] Includes West Virginia, but practically the total production was from Virginia.

A good idea of the distribution of the different varieties of iron ore produced in Virginia in 1908 may be gained from the table below, in which the total production is classified by varieties and counties. Brown hematite, which constitutes at present the chief ore, comes mostly from the Appalachian counties west of the Blue Ridge, with only a minor production from the counties in the crystalline area. The same is true for the production of hematite, which now stands next in importance to brown hematite. Deposits of magnetite are widely distributed through the crystalline area, which form important reserves of iron ore, but the production of magnetite in the State has been very small and of minor importance.

Production of Iron Ore by Counties and Varieties, in long tons.

County	Brown hematite Long tons	Value	Red hematite Long tons	Value
Alleghany	146,118	$ 382,334	(a)	$ (a)
Augusta Botetourt Craig	173,849	406,795	35,348	57,703
Carroll	22,759	34,139		
Lee			(a)	(a)
Pittsylvania	5,979	13;164	(a)	(a)
Warren			(a)	(a)
Pulaski	83,239	134,273		
Roanoke Rockbridge	27,002	41,745		
Washington Wythe	168,954[b]	322,309		
Total	627,900	$1,334,759	64,323	$130,932

[a] Includes 28,975 long tons of red hematite, valued at $73,229, from Alleghany, Lee, and Pittsylvania counties.

[b] Includes a small production of mangetite from Washington county.

The average price per long ton of the different varieties of iron ore produced in Virginia during the years 1906, 1907, and 1908 follows: 1906, brown hematite $1.90, hematite $1.94, magnetite $3.08; 1907, brown hematite $1.95, hematite $1.96, magnetite $3.27; 1908, brown hematite $2.13, hematite $2.04 and magnetite $2.00. These prices represent the value of the ore at the mouth of the mine, and are taken directly from the replies of the producers.

The production of pig iron in Virginia in 1908 amounted to 320,458 long tons, valued at $4,578,000, as compared with 478,771 long tons in 1907, valued at $8,963,000, a decrease in quantity of 158,313 long tons or 33.07 per cent., and in value of $4,385,000 or 48.92 per cent. The production in 1908 was less than that of any year since 1898.

Of the 1908 production,[c] 377 tons were classed as Bessemer and low phosphorus pig, 17,900 tons as forge iron, 34,338 tons as basic pig iron, and the remainder, 267,843 tons, was principally foundry pig iron.

There is given in the table below the production of pig iron in Virginia for the years 1905, 1906, 1907, and 1908.

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[c] Birkinbine, J. Personal communication.

Production of Pig Iron in Virginia by years, 1905-1908.

Year	Blast Furnaces				Production in long tons	Value	Value per ton
	In Blast June 30	December 31					
		In	Out	Total			
1905	....	......	......	......	510,210	$7,540,000[a]	$14.78
1906	14	14	11	25	483,525	8,591,000[a]	17.77
1907	16	7	19	26	478,771	8,963,000	18.72
1908	9	10	16	26	320,458[b]	4,578,000	14.29

[a] Estimated.

[b] Birkinbine, J. Personal communication.

MANGANESE ORES

Virginia has more known deposits of manganese, they extend over a larger territory, a larger number of localities has been worked, and more manganese has been produced than in any other state in the Union. Manganese ores occur in each of the three major geologic provinces of the State, namely, the Coastal Plain or Tidewater belt, the Piedmont province or crystalline area, and the Appalachian Mountains province or Paleozoic area. Of these the Mountain (Valley) province has yielded the principal production, with extensive operations and a large total production from the Piedmont province. Only a slight production has come from the eastern or Coastal Plain province.

The beginning of manganese mining in Virginia and perhaps in the United States, was in 1857, when 100 tons of ore were reported taken from the lands of Joshua Robertson, about 5 miles from Waynesboro, Augusta county. In 1868 and 1869, about 5,000 tons of manganese ores were mined near Warminster, Amherst county, which really marked the beginning of systematic mining of manganese ores in the State. The total production of manganese in Virginia prior to 1869 amounted to 5,684 long tons taken principally from the Crimora mine in Augusta county.

Manganese occurs natively in a variety of mineral combinations but only the oxides of the metal are of commercial importance in Virginia. Of these, pyrolusite and psilomelane greatly predominate with, in places, much of the earthy oxide, wad. These different oxides often occur admixed in varying proportions. The ore is frequently partially or entirely crystalline, of a dark steel-blue color, and the nodular (kidney) type, which usually prevails, often displays the complete or partially layered structure of concretionary masses.

The manganese ores are usually found imbedded in the residual clays which overlie the rocks, from which the clays have been derived by the usual processes of decay. The underlying rock yielding the ore-bearing clays may be of sedimentary or igneous origin, and may be the usual consolidated sediments, or a metamorphic crystalline type.

The ore is distributed through the clays in an irregular manner in the form of pockets or lenticular masses, rarely as distinct beds; as veinlets and stringers cutting the clays in all directions; as single nodules and masses, ranging in weight up to 500 pounds, assembled in the clays; as small disseminated grains scattered through the clays; as breccia ore in large masses; and as probable replacement and cavity fillings in sandstone or sandy clay. In places, both in the Piedmont and Valley regions, the ore distribution conforms in a general way to the bedding of the inclosing clays; frequently, however, this is obscured and the ore bodies indiscriminately cut the clays in all directions.

In the Piedmont region where the residual clays have been derived from the decay of crystalline schists, and the original schistosity of the rocks preserved in the clays, the ore frequently conforms with the foliation and is disposed in thin stringers and sheets much after the manner of interleaving. The pockets show much variation in size and number, ranging from small nests to bodies yielding many tons of ore. They are rarely composed of solid ore free from clay, but the ore forms thickly-studded nodules in the clays. The pockets may be closely spaced or they may occur at wide intervals, usually not connected, although at times stringers or irregular nodules may lead from one pocket to another.

The principal productive manganese deposits in Virginia are (1) those of the Piedmont region, occurring chiefly in Campbell and Nelson counties, northeast and south of Lynchburg; and (2) those of the Valley region occurring along the west slope of the Blue Ridge.

Numerous mines have been worked in the Piedmont region, but that of the Piedmont Manganese Company, near Mount Athos, and the Theresa mines, near Otter river, in Campbell county, were the only producers of manganese ore in 1908. The ore occurs in nodular masses in residual clay derived from metamorphic crystalline rocks.

In the Valley region the principal manganiferous ore belt lies along the west slope of the Blue Ridge. Workable deposits of manganese ores have been found in each county bordering on the western slope of the Blue Ridge. The Blue Ridge iron ore mines occur along this belt, many of which contain some manganese in the form of manganiferous iron ore, and similarly many of the manganese deposits contain some iron. The manganese ores are usually found embedded in residual clays derived from Cambrian ferriferous shales, which overlie the Cambrian quartzite. In other places over the Valley region, manganese ores occur similarly embedded in residual clays derived from limestone of Cambro-Ordovician age. Of the numerous mines worked along this belt, Staley's Creek Manganese and Iron Company, near Marion, in Smyth county, the Dry Run in Page county, and the Crimora, Lyndhurst, and Vesuvius mines in Augusta county, were the only ones operating in 1908. The famous Crimora mine in Augusta county has produced more manganese ore than all other mines in the United States combined.

The nature of the manganese ores mined in Virginia is one of irregular distribution, in the form of nodules and pockets, through residual clays, which range in thickness from a few feet up to several hundred feet. The ore distribution varies considerably and the deposits are limited both vertically and laterally. The method of mining will depend largely upon the location of the deposits and their depth below the surface. Open-pit and cut, shaft and tunnel work are employed. These are often used together to advantage in a single place. In most cases of tunneling and shafting in the larger operations, timbering is necessary on account of the liability of caving of the clays.

Usually the only treatment of the ore necessary before shipping is to free it from adhering clay. Crushing and jigging are necessary in the spongy or porous type of ore, the numerous cavities of which are filled with clay; also in those ores containing considerable free quartz grains and cemented fragments of the rock. Washing will usually suffice for cleansing the bulk of the ore. In the crushed and jigged ore subsequent washing is also necessary. For washing the ore, the ordinary log washer is used similar to that used for cleansing brown iron ores.

Virginia has always been the principal producer of manganese ores in the United States. The figures of production in 1908 were 6,144[a] long tons, valued at $62,776, as compared with 4,604 long tons, valued at $56,469, in 1907. This represents a gain of $6,307 or 10.4 per cent. There were seven producers of manganese ores operating in five counties, as follows: Augusta, Campbell, Page, Smyth, and Warren, with the principal production from Augusta and Campbell counties. The ore mined is reported to have averaged 51.06 per cent. of metallic manganese, and up to 10 per cent. of metallic iron. The average value per ton of manganese ore was $10.22, as against $12.27 in 1907.

There are given in the table below the figures of production and value of manganese ores in Virginia from 1903 to 1908, inclusive:

Production and Value of Manganese Ores in Virginia, 1903-1908.

Year	Quantity Long tons	Value	Average value per ton
1903	1,801	$19,611	$10.89
1904	3,054	28,406	9.30
1905	[a]3,947	35,209	8.92
1906	6,028	77,522	12.86
1907	4,604	56,469	12.27
1908	[b]6,144	62,776	10.22

[a]In addition, 453 tons of tailings, valued at $406, were shipped.
[b]In addition, 274 tons of manganiferous iron ore were sold.

GOLD AND SILVER

The Virginia Mining Company of New York, operating between the years 1831 and 1834 the Grasty tract of land in Orange county, was the first gold mining company incorporated in Virginia. In 1836, there was considerable activity in gold mining in the State, and the production was reasonably steady from the rediscovery in 1831 to 1850, the annual value being given between $50,000 and $100,000. Increased activity in gold mining in the State was manifested in the early fifties, but the Civil War almost completely stopped mining operations in Virginia and in the South generally. Considerable activity was

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[a] In add on, 274 tons of manganiferous iron ore were sold

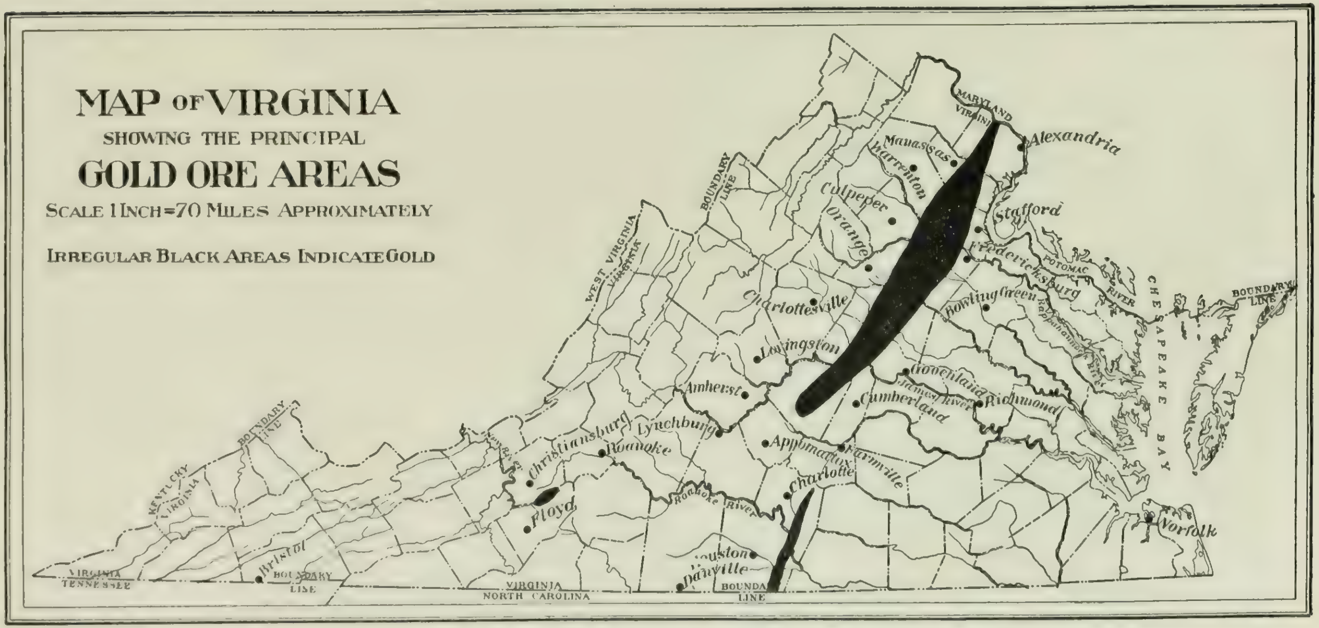

Fig. 9.—Map of Virginia showing the principal gold ore areas.

again manifested in the Virginia gold fields after the close of the Civil War, and milling and reduction plants were erected at various points. Many of these attempts met with only small success and in most cases were abandoned, not because of the lack of ore but because largely of bad management and inexperienced mining, together with the refractoriness of the Virginia ores.

Map, figure 9, shows the location of principal areas in Virginia from which gold has been mined. These are arranged in a belt which begins in Montgomery county, Maryland, and extends across Virginia in a southwestward direction to the North Carolina line. The belt varies in width from 15 to 25 miles, and is 200 miles long, covering an area of some 4,000 square miles, with its best developed portion in Fauquier, Stafford, Culpeper, Orange, Spottsylvania, Louisa, Fluvanna, Goochland, and Buckingham counties. Gold is also found in Appomattox, Prince Edward, Charlotte, Halifax, and Pittsylvania counties, which mark the southwest extension of the principal belt. Excepting Halifax, which has been a producer for several years, no developments have been made in the last-named counties.

A smaller belt occurs on the west side of the Blue Ridge in Montgomery, Floyd, and Grayson counties, but is undeveloped and has proved of little economic importance. The work done has been mostly in the nature of sluicing and panning.

Many of the mines in the principal belt have produced large quantities of gold, as shown in the United States mint returns, and have been rather extensively worked. Preparations are in progress for the resumption of mining at a number of the mines in the principal belt during the year 1909. The mines in Fauquier, Stafford, Culpeper, Orange, and Spottsylvania counties are grouped about and near the junction of the Rappahannock and Rapidan rivers in a belt about 15 miles wide. This principal belt is crossed by innumerable streams bordered by placers.

The principal rocks of the Virginia gold belt are micaceous schists and gneisses, often garnetiferous and chloritic, and in places hornblendic. They include both altered sediments and igneous masses. The prevailing strike is N. 20° to 30° E., and the dip is toward the east and southeast at varying angles, frequently steep, and in many cases nearly vertical. Granite masses and basic igneous rocks occur in the region, sometimes sheared from dynamic causes.

The gold-bearing veins are chiefly quartz, which vary in texture from large crystalline masses to very fine saccharoidal grains. In structure, they vary from massive to thin platy or schistose bodies, both usually penetrated by closely spaced irregular fractures. The principal metallic content is auriferous pyrite, which at times is copper-bearing and contains more or less admixed chalcopyrite. Within the weathered zone, extending from the surface down to local water-level and accordingly of varying depth, the quartz is more or less porous and discolored or stained with iron oxide from the oxidation of the sulphide minerals, and the liberation of free or elementary gold. Below the local water-level the veins are fresh, the sulphides are unaltered, and elementary gold is less frequent in occurrence. The early operations were confined largely to the oxidized portions of the veins which yielded a free-milling ore that was easy of treatment. Since then, operations chiefly include the mining of sulphurets or the sulphide bodies, which require a different metallurgical treatment of the ores in order to extract and recover the gold.

The gold-bearing veins conform in the main to the structure, strike and dip of the inclosing rocks, a fact which has caused various explanations to be advanced for their origin by different observers. Although the veins conform in the main to the dip and strike of the inclosing rocks, the correspondence is far from being exact, for they frequently cut the schists at small angles both in dip and strike. This evidence is sufficient to establish the fact that the formation of the veins post-dates the schistose structure of the inclosing rocks. The vein structure is irregular lenticular, varying in width from a few inches to as many feet, and often the lenticular stringers are discontinuous. One stringer may dwindle to a thread or disappear and is replaced by another or by others. Some of the veins are remarkable for their persistence and continuity.

Excepting quartz and pyrite, the gangue minerals in the gold veins of Virginia comprise the following species: Chalcopyrite, native copper, galena, mispickel (arsenopyrite), pyromorphite, tetrahedrite, tourmaline, vanadinite, sphalerite, pyrrhotite, and sidedite. So far as the gangue minerals are concerned, the Virginia gold ores are entirely typical in character. The ores are quartzose deposits in which pyrite is usually present, chalcopyrite common, mispickel and sphalerite are not rare.

In 1904, the production of gold and silver in Virginia was contributed to by eleven counties. From the United States mint returns for 1905, the gold production in Virginia increased in value, over 1904, $1,182; and silver decreased $3,779. In 1905, seven mines were reported producing, three of which were placer mines. According to Lindgren, the four deep mines yielded an estimated tonnage of 800, with an average value of $5.35 per ton in gold and silver. The production in 1906 showed an increase over that of 1905 of $9,850 in gold and $61 in silver. There were 9,565 short tons of siliceous ores raised which yielded an average extraction of $4.17 per ton. There was no reported production for the year from placer mines. In 1907, the total production of gold was valued at $8,288 and of silver $146, a decrease from that of 1906. According to McCaskey, seven mines reported a production, six of which were deep mines, yielding 26,822 short tons of ore. Of this, 1,128 short tons were siliceous ores which yielded an average extraction of $7.33 per ton in gold and silver; 25,044 short tons were siliceous and cupiferous sulphide ores, giving an extraction of $0.002 per ton in the precious metals; and the remainder were lead ores which yielded no gold or silver.

Four placers and four deep mines reported a production in 1908. According to McCaskey, the deep mines reported 12,877 tons of ore, 230 tons of which were siliceous gold ores, with an average value in precious metal of $7.135 per ton, and 1,896 tons were copper ores yielding $0.05 in precious metals and 12.4 pounds of copper per ton. Eight hundred (800) tons of lead ores yielded gold and silver valued at $0.28 and 95.2 pounds of lead per ton.

Virginia produced, in 1908, 118.57 fine ounces of gold valued at $2,451, and 236 fine ounces of silver valued at $125. This shows a decrease from the production of 1907 in gold of 283.43 fine ounces in quantity, and of $5,849 in value, and a decrease in silver of $21 in value, but an increase of 15 fine ounces in quantity.

There is given in the table below, compiled from the production reports of the United States Mint and Mineral Resources of the United States, the production of gold and silver in Virginia by years.

Production of Gold and Silver in Virginia by years.

Year	Value	Year	Value
1799–1879	$3,091,700	1894	$ 7,643
1880	11,500	1895	6,325
1881	10,000	1896	4,466
1882	15,000	1897	Not given.
1883	7,000	1898	4,500
1884	2,500	1899	7,160
1885	3,500	1900	3,200
1886	4,000	1901	5,720
1887	14,600	1902	6,227
1888	7,500	1903	18,630
1889	4,113	1904	7,686
1890	6,496	1905	5,122
1891	6,699	1906	15,000
1892	5,002	1907	8,434
1893	6,190	1908	2,576

In the subjoined table are given the quantity and value of gold and silver produced in Virginia for the years 1906, 1907, and 1908.

Production of Gold and Silver in Virginia by years, 1906-1908.

Year	Gold		Silver	
	Quantity in fine ozs.	Value	Quantity in fine ozs.	Value
1906	717.50	$14,832	250	$168
1907	400.93	8,288	221	146
1908	118.57	2,451	236	125

COPPER

Copper ores are found in many counties of the State and in a variety of occurrences. They are confined to the crystalline rocks of the Piedmont Plateau and the Blue Ridge mountains, and to the Triassic red beds, which form numerous small areas in the Piedmont province.

The known geographic areas of these ores in the State are:

I. THE PIEDMONT REGION:
  (1) The Virgilina district, which includes Halifax and Charlotte counties in Virginia, and Person and Granville counties in North Carolina.
  (2) The deposits on or near Southwest Mountain in Albemarle county, and those near New Canton, Arvonia, and Dillwyn, in Buckingham county.
  (3) The pyrite bodies in Louisa, Stafford, and Prince William counties, mined principally for their sulphur content, but carry at times sufficient copper to warrant saving.

II. THE NORTHERN BLUE RIDGE REGION:
  Includes those deposits from near Front Royal southward, embracing parts of Warren, Fauquier, Rappahannock, Madison, Page, and Greene counties.

III. THE SOUTHWEST VIRGINIA REGION:
  Includes the "Gossan Leads" of the Floyd–Carroll–Grayson counties plateau.

IV. THE TRIASSIC AREAS:
  Includes deposits chiefly in Loudoun, Culpeper, and Orange counties.

Geologically, the copper ores are confined to the crystalline rocks, either the schists and gneisses or the massive igneous rocks of the Piedmont and Blue Ridge provinces, and to the red shale-sandstone series of the Triassic areas. In the Virgilina district, the ores occur in quartz-fissure veins which intersect or lie in an altered andesite (meta-andesite) and associated tuffs of probable pre-Cambrian age. The ores of the northern Blue Ridge region are segregated in and disseminated through basaltic flows of pre-Cambrian age, rocks designated by Keith as Catoctin schist. The "Great Gossan Lead" of the Floyd-Carroll-Grayson counties plateau, in southwest Virginia, is a mineralized faulted zone in schists of doubtful age, probably pre-Cambrian in part. The rocks are in part altered sediments and in part altered igneous masses of basic and acid types, principally the former.

The Virginia copper deposits may be grouped into five types:

(1) Pyrite masses in schistose rocks worked chiefly for their sulphur content, but containing enough copper in places to be saved. The well-known and extensively worked pyrit bodies near Mineral, in Louisa county, and near Dumfries, in Prince William county are the best representatives of this type.

(2) Pyrrhotite veins containing chalcopyrite and some pyrite in schistose rocks referred to usually as the Ducktown, Tennessee, type, the most productive copper district in the South. The best representative of this type in Virginia is the "Great Gossan Lead" in Carroll county.

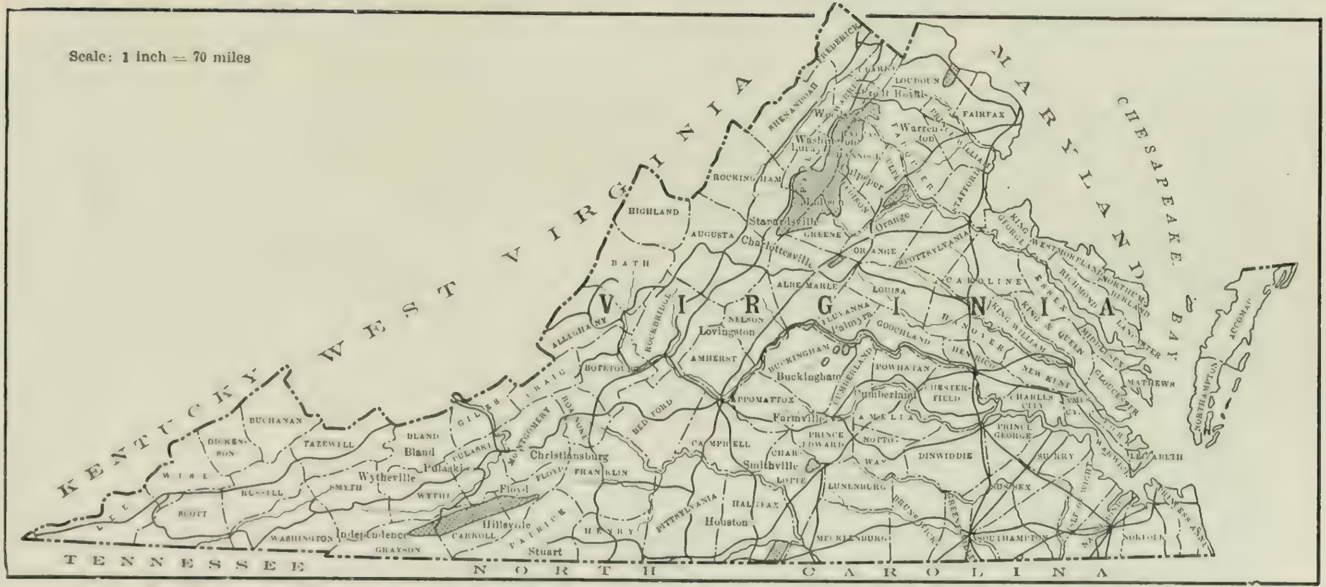

Fig. 10.—Map of Virginia showing distribution of the principal copper areas. Cross-lined areas represent copper.

(3) The Virgilina type in Virginia and North Carolina which represents quartz-fissure veins carrying chalcocite (copper glance) and bornite (horse flesh ore), with little or no pyrite and chalcopyrite, in volcanic rocks of intermediate character and their associated tuffs.

(4) The northern Blue Ridge or Catoctin type, the ores of which are chiefly native copper and cuprite with small amounts of the carbonates, azurite and malachite, and very rarely copper sulphides associated with epidote and quartz in a basic volcanic rock, and as grains disseminated through the rock.

(5) The Triassic type, representing sparsely disseminated copper ores, chiefly malachite and sulphide, and phosphate of copper, in sandstones and shales of Triassic age.

In addition to these five types, copper in the form of the mineral chalcopyrite is a frequent associate with gold in the gold-bearing quartz-pyrite veins of the Virginia gold belt of the Piedmont province. Copper has not been observed, however, at any locality within the State in this mode of occurrence to be regarded as of commercial value.

Mining operations for copper in the State have been confined principally to three districts; namely, the Virgilina district, the northern Blue Ridge district, and the "Great Gossan Lead" district. Isolated deposits, which do not properly fall within either of these three districts, have been exploited in a number of localities, confined almost exclusively to the Piedmont counties.

The Virgilina copper district is, commercially, the most important district in Virginia, and is being studied and mapped on a large scale by the State Survey, after the completion of which a detailed report will be published and distributed. It derives its name from the town of Virgilina, located on the Virginia-North Carolina boundary, forty-seven miles east of Danville on the Atlantic and Danville division of the Southern Railway. The Norfolk and Western and the Richmond and Danville railroads lie not far to the north and west.

The principal developments in the district, which include a large number of mines, are confined to an approximate north-south distance of eighteen miles, and an average width of from two to three miles. The present productive portion of the district has about equal extension in the two states, Virginia and North Carolina. The country rock is schist, derived principally from intermediate and acid volcanic rocks and their associated tuffs. The schistosity of the rock strikes N. 10° to 20° E. and dips eastward from 70° to 80°. The quartz veins, of which there are many, are usually more or less parallel, and strike N. 5° to 10° E., with considerable variations from this direction in places. Mining developments show that copper occurs in most of the veins in greater or less quantity. The veins are lenticular bodies of quartz which, in some cases, show very uniform continuous outcroppings at the surface. The workable ores comprise chalcocite or glance (copper sulphide) and bornite (copper-iron sulphide) in a siliceous gangue. Small masses of calcite and feldspar are occasionally noted as gangue minerals. Cuprite (copper oxide), malachite and azurite (green and blue carbonates of copper) occur as alterations of the original sulphides. Some native copper is noted in places. Chalcopyrite and pyrite are almost entirely absent. The worked ores are free from arsenic and antimony, but carry values in both silver and gold, particularly the former.

The High Hill mine, the most northerly mine in the developed portion of the district, is developed by numerous shafts and levels, the deepest shaft being about four hundred feet. Up to 1904, this mine had produced a total of 167,000 tons of ore which averaged about 15 per cent. of copper; the richest carload showed on sampling 27.83 per cent., the poorest 7.6 per cent. The company has produced 212,455 pounds of refined copper and 2,485 pounds of refined silver. The concentrates carry $4.00 per ton in gold.

At the Seaboard Copper Company's mine, north of Virgilina, the new 100-ton concentrating mill was recently completed, which makes very clean concentrates of bornite and chalcocite from the siliceous ores. This mine is developed by 600 feet of shafts and 400 feet of levels, the greatest depth reached in 1908 being 265 feet. The Little John mine, located a short distance southwest of the Seaboard mine, shows encouraging results.

Several smaller operations have been developed in the most northerly extension of the Virgilina district near Drakes Branch in Charlotte County.

The "Great Gossan Lead" of Floyd, Carroll, and Grayson counties is a vein traceable for some eighteen miles. It is composed chiefly of pyrrhotite with admixed quartz and schist, and carries streaks and patches of chalcopyrite and pyrite. The vein fills a fault fracture in crystalline schists, varies in width from a few feet to one hundred feet, shows a somewhat variable but average dip of about 45°, and has in general an approximate northeast trend. The region was actively prospected in the early fifties, and the rich secondary copper ores found beneath the gossan were boxed and shipped to Baltimore. During 1854-5, there were eight producing mines on the "Gossan Lead"; the aggregate amount of ore shipped for the six months from January, 1855, to July, 1855, being 1,454,363 pounds. The ore averaged about 25 per cent. copper, and at that time the metal was worth twenty-six cents per pound. The copper content of the sulphide masses is too low (averaging less than 1 per cent. metallic copper) to work for copper alone, but the vein is mined on Chestnut Ridge and the ore treated at Pulaski for sulphur, so that the residue is available for copper.

The northern Blue Ridge region, which extends from near Front Royal southward, embracing parts of six counties, has been extensively prospected, and many mines have been developed, but as yet with little production of the metal. The Virginia Consolidated Copper Company's mine, located near Ida post-office, about five miles southeast of Luray, has reached a maximum depth of 308 feet. The ores of the Blue Ridge region consist chiefly of cuprite and native copper, small amounts of green and blue carbonates, and less of the sulphides, bornite and chalcopyrite. The native copper often occurs as nucleal masses surrounded by cuprite. Bornite is in excess of chalcopyrite. The ore occurs along crevices and joints in small, irregular-shaped lenses of quartz, and as disseminated grains through the more epidotized portions of the basalt. It occurs mostly where the rocks are fractured and epidotized. When ore-bearing, the rocks are yellowish green in color, due largely to the formation of epidote and, in part, of chlorite.

During the early part of the last century, attempts were made to mine the sparsely disseminated copper ores in the red sandstones and shales of Triassic age over parts of Loudoun, Culpeper, and Orange counties. While considerable work was done, the ores appear to be too generally diffused in the rocks to be of commercial value. No veins have been found and no well-defined horizons are known, the ores occurring for the most part as films or thin coatings of malachite on the joint surfaces, and as disseminated grains of the sulphide and phosphate of copper through the rocks. Rich specimens of copper glance and copper phosphate are sometimes obtained, but they are by no means abundant.

The production of copper in Virginia during 1908 was 24,775 pounds, valued at $3,270, as compared with 58,880 pounds in 1907, valued at $11,776, a decrease of 34,105 pounds in quantity and $8,506 in value.

LEAD AND ZINC

Lead mining in Virginia dates back more than 150 years, and the old lead mines at Austinville on New river, in Wythe county, were the first to be worked. For many years after the Virginia mines were operated, mining was confined exclusively to the lead ores. Zinc ores were first discovered at Bertha near Austinville, in Wythe county, during the year 1876. Mining of zinc ores in Virginia dates from the opening of the mine at Bertha in 1879, when a small shipment of ore was made to Providence, Rhode Island. The metal obtained from these ores proved to be of such rare purity that attention was directed at once to them, and a smelting plant was built at Pulaski, which was later re-

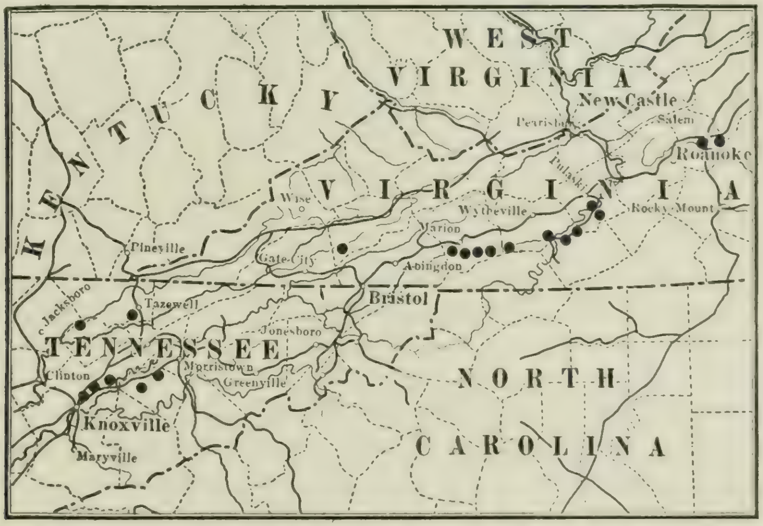

Fig. 11.—Map of southwest Virginia and east Tennessee, showing distribution of lead and zinc ores. Lead and zinc deposits indicated by heavy dots. Scale, 1 inch = 120 miles.

modeled and enlarged, and is owned and operated at present by the Bertha Mineral Company. The "Bertha" spelter is of exceptional purity, and has a world-wide reputation.

Excepting the single deposit in the extreme southwestern part of Albemarle county, the known deposits of lead and zinc in Virginia are limited to the Valley province west of the Blue Ridge. All mining and prospecting for lead and zinc ores in this province have been confined to the western half, extending from and including Roanoke county on the east to and including Scott county on the southwest. Ores of lead and zinc are known to occur either sparingly or in quantity in the following counties: Roanoke, Montgomery, Pulaski, Wythe, Smyth, Bland, Tazewell, Russell, Scott, and Albemarle. Of this number, only one county, Wythe, has shown as yet producing mines. More or less prospecting has been attempted in the majority of the counties named above, and small amounts of the ore have been mined in a number of them.

Geologically, the occurrence of lead and zinc ores in southwest Virginia is limited to the magnesian limestone of Cambro-Ordovician age, known as the Shenandoah or Valley limestone. The known commercial deposits of these ores occur near the eastern side of the Valley, though several promising prospects are opened near the western side. Map, figure 11, shows the location of the principal openings worked for lead and zinc in southwest Virginia and east Tennessee.

The ores include (1) the original sulphide forms sphalerite (sulphide of zinc), galenite (sulphide of lead), pyrite (sulphide of iron), and in several places chalcopyrite (the double sulphide of iron and copper); and (2) the secondary or oxidized forms which have been derived from the original sulphides and occur in the residual clays derived by weathering from the limestone. These include calamine (hydrous silicate of zinc), smithsonite (carbonate of zinc), and cerussite (carbonate of lead). Named in the order of their importance, dolomite, calcite, barite, fluorite, and quartz are the associated non-metallic minerals.

The bulk of the sulphide ores belong to the disseminated replacement breccia type. Little or no replacement of the limestone by the ore is indicated in some places. The zones of breccia ore are associated with faulting and folding. Not all parts of the breccia zones are mineralized, but the ore is distributed at irregular intervals. The oxidized ores usually show much richness, and are often concentrated in massive form as large irregular masses and layers, principally at and near the bottom of the residual clays, closely hugging the irregular weathered surface of the limestone. Until recently only the oxidized or secondary ores have been mined. These have been practically exhausted and attention is now directed to mining the original sulphide ores in the fresh limestone.

The ores are shipped to Pulaski, and smelted at the zinc smelting plant of the Bertha Mineral Company. Three grades of spelter are made branded according to purity: "Bertha Pure Spelter," "Old Dominion," and "Southern."

The single deposit of lead and zinc ores in Albemarle county is the only type of its kind known in the South. The mine is owned by the Albemarle Zinc and Lead Company, and is located two miles slightly north of east from Faber. The associated rocks are metamorphic crystalline schists, cut by dikes of diorite and diabase. The metalliferous vein, traced for a distance of several miles, averages about four feet in width, strikes N. 45° E., and dips 80° to 85° northwest. Where opened, the vein is of the lenticular type, composed of bulbous bodies of fluorspar and some quartz through which the ore, blende and galena, is distributed. The ore is treated in an 80-ton mill erected at the mine.

The production of lead in Virginia in 1908 was 38 short tons, valued at $3,200, as compared with 82 short tons in 1907, valued at $8,692, a decrease of 44 short tons in quantity and $5,492 in value. The production of spelter in Virginia in 1906 was 1,143 short tons, valued at $139,446; in 1907, 771 short tons, valued at $90,978; and in 1908, 705 short tons, valued at $66,315. This is a decrease in 1908 from 1907 of 66 short tons in quantity and $24,663 in value.

TIN

Though not a producer of tin, the existence of tin ore in Virginia in the Irish Creek area of Rockbridge county has been known for many years, and in 1883 and later the deposits were opened in several places. The Irish Creek area is about 4 miles long in a northeast-southwest direction and 3 miles wide, embracing a total area of 12 square miles.

The immediate rocks of the area are of granitic composition, composed principally of a coarse aggregate of quartz and feldspar (orthoclase and albite), with hornblende, and in places some epidote. Dikes of fine-grained altered diabase cut the granitic rocks in all directions, and apparently are frequently associated with the tin-bearing veins.

The tin ore (cassiterite) occurs principally in greisen veins, which traverse the granite in all directions and have steep though varying dips. The veins are usually narrow, not exceeding a foot and less, though a greater thickness is frequent and some of the veins measure several feet across. The cassiterite is disseminated in small crystals and fine grains indistinguishable to the naked eye. The associated minerals comprise wolframite, mispickel (arsenopyrite), pyrite, and beryl. In addition to these, siderite, limonite, chlorite, muscovite, damourite, and fluorspar have been reported. The mispickel is reported by McCreath to contain both gold and silver.

The Irish Creek tin area was carefully examined in 1885 by the late Major Hotchkiss, who concluded his report on the area as follows: "In conclusion, this report is emphasized by the opinion that this Irish Creek tin-bearing district, as above described, will prove abundantly productive in tin."

NICKEL AND COBALT

The existence of nickel in Virginia has been reported from a number of localities in the Piedmont region, especially in association with the extensive pyrrhotite bodies of the Floyd-Carroll-Grayson counties plateau in southwest Virginia, and in Amherst county east of Lynchburg. More recently nickel in association with peridotite masses has been reported from near Broadrun station in Fauquier county. In addition to the above occurrences, cobalt is found in association with some of the impure earthy manganese deposits of the Valley region, especially along the western base of the Blue Ridge.

Probably the most encouraging locality in the State from which nickel has been reported is in the northern part of Floyd county, where the Virginia Nickel Corporation has done considerable exploratory work on Flat Run and Lick Fork. The Lick Fork openings are the principal ones in the area, and the ore is chiefly pyrrhotite with some chalcopyrite. At the time of my visit in May, 1907, a large amount of ore on the dump was reported to average by actual assays not less than 1.75 per cent. of nickel and a fraction of 1 per cent. of copper. As much as 0.4 per cent. of cobalt was reported, but the average is considerably less. Assays of the pyrite from other openings in the area are reported to yield from 3 to 4 per cent. of nickel.

The rocks immediately associated with the ore are, without exception, of igneous origin, and comprise pyroxene syenite, diabase, and gabbro. These are intruded into the country schists and gneisses. The gabbro and diabase penetrate the pyroxene syenite in dike-like forms and are accordingly younger in age. The mica-gabbro is the ore-bearing rock. In some parts of the gabbro, the sulphides are sparingly present, in others they make up 50 per cent. and more of the total rock mass, with all gradations between.

COAL

The first coal mined in the United States was in the Richmond basin, where mines were opened and worked on the James river, near Richmond, as early as 1750. For the next 71 years, or from 1750 to 1822, there are no available records of production from the mines near Richmond; the first year for which figures of production are given is 1822, when 54,000 short tons of coal were mined. The production from the Richmond basin continued to increase until 1832 (the production in 1828 being 100,280 tons), when it began to decline.

The construction of the Norfolk and Western Railway through southwest Virginia in 1882, opened up the famous Pocahontas coal district, which lies partly in Virginia. Likewise, the building of the Clinch Valley division of the Norfolk and Western Railway, nine years later, marked the beginning of the development of the Wise county coal district. The developments in these two fields in southwest Virginia, Tazewell county in 1883 and Wise county in 1891, again restored Virginia to importance as a coal producer.

Coal was mined in the Montgomery-Pulaski counties area prior to the Civil War, but not in an extensive way. It is reported that some of the coal used in the bunkers of the *Merrimac* (Virginia) in her fight with the *Monitor,* in Hampton Roads, came from the Price mountain mines in Montgomery county. For a period of 30 years after the Civil War, the only mining carried on in this field was to supply a limited local market. Within recent years larger developments have been made, and until the beginning of the financial panic in the latter part of 1907, the production was correspondingly increased.

Map, figure 12, shows the distribution of coal areas in Virginia. As is indicated on the map, coal is mined in two of the three major provinces of the State, namely, the Mountain province and the Piedmont province. Of these, the coal deposits of the Mountain province are the only producing ones at present, although recent developments in the Piedmont province will undoubtedly restore this area again to the rank of a producer.

The Virginia areas which have produced or are producing coal are as follows:

I. The coal deposits of the Piedmont province. Includes the Richmond Coal Basin, which covers parts of the following five counties: Henrico, Chesterfield, Powhatan, Goochland, and Amelia. This is the only area of free-burning coal in the eastern portion of the United States that is located immediately adjacent to tidewater. The Farmville area, which covers parts of Prince Edward, Cumberland, and Buckingham counties.

II. The coal deposits of the Mountain province, which include a number of separate areas extending across the State in a southwesterly direction from Frederick county on the north to the Tennessee boundary on the south.
   (1) The Frederick County Area. Including the Mountain Falls district in the southwestern portion of the county and near the West Virginia line.
   (2) The Augusta County Area. Includes the North River district in the northwest corner of Augusta county and the contiguous part of Rockingham county.
   (3) The Botetourt County Area. Includes the southwest corner of Botetourt county.
   (4) The Montgomery–Pulaski Counties Area. Includes Price and Brush mountains in Montgomery county, and Cloyd and Little Walker mountains in Pulaski county.
   (5) The Bland–Wythe Counties Area. Includes a small area in the southern part of Bland county and in the northern part of Wythe county.
   (6) The Southwest Virginia Area. Forms the southeastern portion of the Kanawha basin, and comprises the Pocahontas or Flat-Top and the Big Stone Gap coal fields of the following counties: Tazewell, Russell, Scott, Buchanan, Wise, and Lee. Of these, Wise and Tazewell counties are the most important producers at present.

Geologically, the Virginia coal deposits are grouped as (1) those of Triassic age, including the Richmond coal basin, and (2) those of

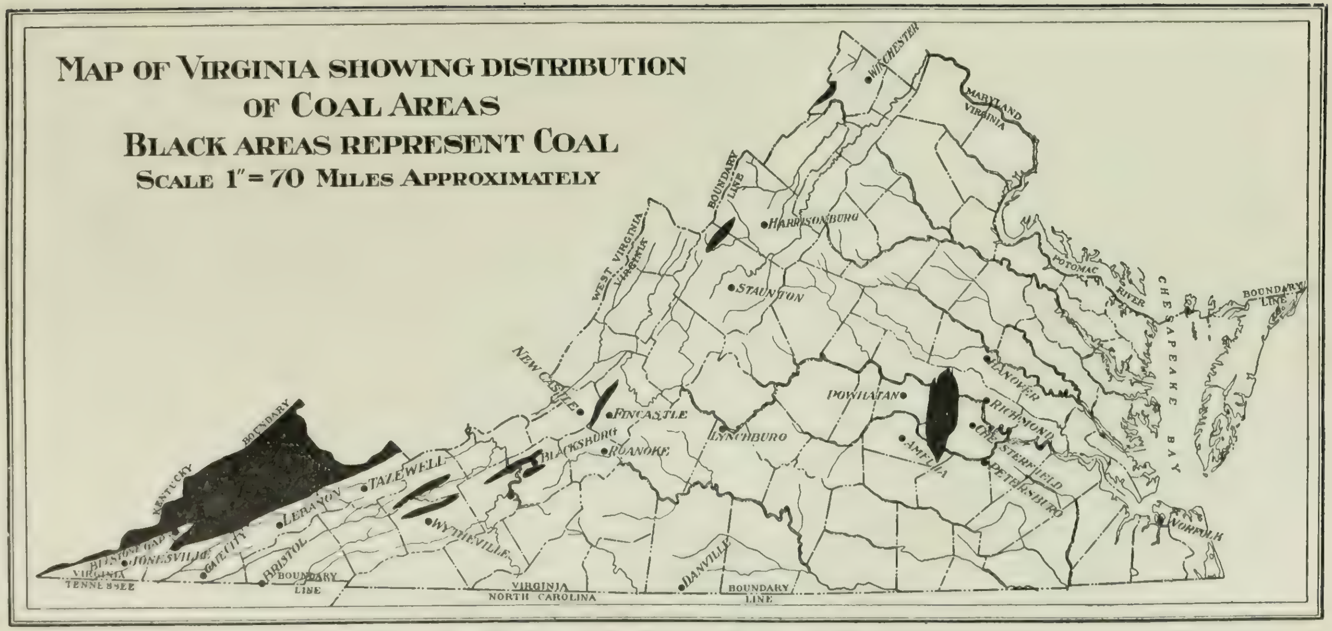

Fig. 12.—Map of Virginia showing coal areas.

Carboniferous age, which includes all coal deposits found west of the Blue Ridge. Of the Carboniferous coal deposits, those of the Mountain Falls district, in Frederick county, the North River area of Augusta county, the North Mountain area of Botetourt county, the Montgomery-Pulaski counties area, and the Bland-Wythe counties area are Mississippian (Lower Carboniferous) in age. The Virginia portion of the Appalachian coal field, which includes the extreme southwest counties along the border of West Virginia and Kentucky, and to which the State owes its rank as a coal producer, is Pennsylvanian (Upper Carboniferous) in age.

The southwest Virginia coal field forms the southwestern part of the Kanawha basin and comprises the following counties: Buchanan, Dickenson, Lee, Russell, Scott, Tazewell, and Wise. Of these, Wise and Tazewell counties are the two most important producers. The other counties contain large reserves of coal, which in places are rapidly undergoing development. Many of these reserves have been made accessible recently through the construction of new lines of railroad, which means increased activity in coal mining in the State and a greater production in the immediate future.

It is due to the southwest Virginia fields that Virginia is entitled to rank among the principal coal-producing states. This area, the Virginia portion of the Appalachian coal field, is estimated to be 1,550 square miles, with the original supply of coal placed at 22,500,000,000 short tons. Campbell and Parker state that from this there had been produced at the close of 1907, a total of 57,229,152 short tons, representing an exhaustion of 86,000,000 tons. "The production in 1907 was 4,710,895 short tons, equivalent to an exhaustion of little over 7,000,000 tons, so that the coal left in the ground in Virginia at the close of 1907 was 2,000 times the exhaustion represented by the production of that year."

The two principal coal fields thus far developed in the Virginia portion of the Appalachian coal field are: (1) The Pocahontas or Flat Top coal field, and (2) the Big Stone Gap coal field.

A goodly number of coal beds are found within the total vertical limits of the geological formations composing the Pocahontas field. Some of these are thin, but at least six workable beds have been opened in places. Not all of these are workable, however, at any one locality, and in places only one is worked. The principal one worked is the Pocahontas vein, No. III, which is 11 feet 3 inches thick. The principal coal-bearing formations in the area are, beginning with the oldest: (1) Coals of the Pocahontas formation, (2) Coals of the Welsh (Clark and Quinnimont of the Pocahontas quadrangle) formation, (3) Coals of the Dismal (Sewell in part of the Pocahontas quadrangle) formation, (4) Coals of the Sequoyah formation, and (5) Coals of the Tellowa formation.

The superior quality of the Pocahontas coal has long established it as the best steam coal in the world. As such it has foremost rank, and it is used on the ocean steamers of the principal nations. It produces an excellent coke, but, as a rule, the lump coal is placed directly upon the market for general purposes, while the slack and fine coal go direct to the ovens for coking.

The Big Stone Gap coal field in Virginia embraces parts of Lee, Scott, and Wise counties. Although opened up nearly ten years after the famous Pocahontas field, it is much the largest producer of coal and coke, and Wise county is the largest coal- and coke-producing county, in the State. This field produces more than 80 per cent. of the coke made in the State.

There are eight workable seams of coal in the district, ranging in thickness from 3.5 to 12 feet, included within a vertical distance of about 1,200 feet. Of these, the four highest have their greatest development in the western part of the district. Campbell divides the measures in this field in descending order, as follows: (1) Wise formation, (2) Gladeville sandstone, (3) Norton formation, and (4) Lee conglomerate. Of these, the Norton is the principal coal-bearing formation. In the eastern portion of the field there are six coal horizons in the Norton formation which afford promise of workable seams at some point within the field. Named in descending order, these are designated by Campbell as follows:

(1) Edwards seam.
(2) Upper Banner seam.
(3) Lower Banner seam.
(4) Kennedy seam.
(5) Imboden seam.
(6) Jawbone seam

Of the numerous coals known to exist in the Norton formation in the Big Stone Gap portion of the field, the Imboden and Kelly seams are more conspicuously developed than the others. Of these, the Imboden seam is the most important one in the district. It can be continuously traced from Norton to the Lee county line, and an excellent grade of coke is made from it.

The coal mining industry in Virginia showed a decided falling off last year, and for the first time in a number of years the output showed a decrease. The production in 1908 amounted to 4,259,042 short tons, valued at $3,868,524, as against 4,710,895 short tons, valued at $4,807,533, in 1907, a decrease of 548,491 tons or 9.59 per cent. in quantity, and $939,009 or 19.54 per cent. in value. The average price per ton of coal in 1908 was $0.91 as compared with $1.02 in 1907. Forty-six operators contributed to the production in 1908, distributed among six counties, as follows: Lee, Montgomery, Pulaski, Russell, Tazewell, and Wise. The accompanying table gives the quantity and value of coal produced in Virginia from 1890 to 1908.

Quantity and value of Coal produced in Virginia, 1890 to 1908, inclusive.

Year	Quantity (short tons)	Value
1890	784,011	
1891	736,399	
1892	675,205	
1893	820,339	
1894	1,299,083	
1895	1,368,324	
1896	1,254,723	$ 848,851
1897	1,528,302	1,021,918
1898	1,815,274	1,070,417
1899	2,105,791	1,304,241
1900	2,393,754	2,123,222
1901	2,725,873	2,353,989
1902	3,182,993	2,543,595
1903	3,451,307	3,302,149
1904	3,583,914	3,076,011
1905	4,275,271	3,777,325
1906	4,254,879	4,183,991
1907	4,710,895	4,807,533
1908	4,259,042	3,868,524

The important developments in the Black Mountain district of Lee county resulted in an increased production of coal in that county in 1908. Wise county, the most important coal-producing county in the State, showed a decrease of 586,972 short tons in 1908, while Tazewell county's production decreased 136,520 short tons. Practically the entire decrease in the 1908 production of coal in the State was in the quantity of coal made into coke. There is given in the table below the production of coal in Virginia from 1900 to 1908, by counties.

Coal Production of Virginia, 1900-1908, by counties, in short tons.

County	1900	1901	1902	1903
Montgomery	9,814	11,177	12,786	20,288
Tazewell	970,866	776,568	723,753	840,195
Wise	1,363,570	1,918,693	2,422,417	2,563,285
Chesterfield				18,084
Henrico	49,504	19,435	24,037[a]	
Pulaski				9,255
Russell				
Lee				
Small mines				200
Total	2,393,754	2,725,873	3,182,993	3,451,307
Total value	$2,123,222	$2,353,989	$2,543,595	$3,302,149

County	1904	1905	1906	1907	1908
Montgomery					6,022
Tazewell	871,720	961,380	910,638	1,116,534	980,014
Wise	2,359,661	2,990,698	3,041,225	3,145,846	2,558,874
Chesterfield	2,100				
Henrico					
Pulaski	177,133[b]	323,073[c]	302,896[c]	448,515[c]	249,671
Russell					
Lee					464,261
Small mines	300	120			200
Total	3,410,914	4,275,271	4,254,879	4,710,895	4,259,042
Total value	$3,302,149	$3,777,325	$4,183.991	$4,807,533	$3,868,524

[a] Includes Chesterfield and Pulaski counties.
[b] Includes Montgomery county.
[c] Includes Lee and Montgomery counties.

The number of employes in the coal mines of the State decreased from 6,670 in 1907, to 6,208 in 1908, and the average number of days worked decreased from 241 to 200, but the average daily production per man increased from 2.93 to 3.43 tons. This increased daily record per man in 1908 over 1907 is attributed in part to the fact that a large number of men were employed in development work in 1907, which reduced the efficiency record for that year.

There were no strikes in the coal mines of the State in 1908, a condition which has obtained for five consecutive years. There is given in the table below the number of hours to the working day in Virginia for the years 1906, 1907, and 1908.

Number of hours to the working day in Virginia, 1906 to 1908.

Year	7 hours		8 hours		9 hours		10 hours		All others
	Mines	Men	Mines	Men	Mines	Men	Mines	Men	Men
1906	......	......	6	105	5	727	31	4,294	5
1907	......	......	......	......	7	849	42	5,791	30
1908	1	80	2	112	10	802	32	5,214	0

Statistics of labor employed in coal mines of Virginia, 1903-1908.

Year	Number of days active	Average number employed
1903	267	5,608
1904	238	5,165
1905	241	5,730
1906	250	5,131
1907	241	6,670
1908	200	6,208
Total	240	34,512

The number of machines used in the coal mines of Virginia increased from 37 in 1906, to 77 in 1907, and 85 in 1908, with a corresponding increase in the tonnage won by machines. The product mined by machines in 1908 amounted to 1,035,832 short tons, or 24.32 per cent. of the total output. The number and kinds of machines in use in Virginia are given in the table below, for the years 1906, 1907, and 1908.

Number and kinds of machines in use in Virginia, 1906, 1907, and 1908.

Year	Pick	Chainbreast	Total
1906	10	27	37
1907	26	51	77
1908	14	73	87

In 1908, 30,872 short tons of coal were worked, yielding 29,745 short tons of cleaned coal and 1,127 short tons of refuse. The subjoined table gives the quantity of coal washed at the Virginia mines in 1906, 1907, and 1908, with the quantity of washed coal and of refuse obtained from it, in short tons.

Coal washed at the mines in 1906, 1907, and 1908, with quantity of washed coal and of refuse obtained from it, in short tons.

Year	Kind of coal	Number of jigs or washers	Quantity of coal washed	Quantity of coal obtained	Quantity of refuse
1906	Bituminous	3	807	767	40
1907	Bituminous	7	33,886	29,386	4,500
1908	Anthracite	4	30,872	29,745	1,127

According to estimates recently made by the United States Geological Survey, the areas containing workable coal in the southwestern part of Virginia cover about 1,550 square miles, and the original content amounted to 21,000,000,000 short tons. The Brushy Mountain field, in Montgomery county, is estimated at 200 square miles in area, with 900,000,000 short tons. The Richmond basin is estimated to cover 150 square miles, with 600,000,000 short tons. The total coal area for the State, therefore, is 1,900 square miles, and the original contents were approximately 22,500,000,000 short tons. There has been mined to the close of 1908, 61,488,194 short tons, equivalent to an exhaustion of approximately 92,000,000 short tons, or 0.4 per cent. of the original total supply.

COKE

The coking coals of Virginia are confined to a few counties in the extreme southwestern portion of the State. The rapid development of the coking-coal fields in this portion of the State during the last few years has given Virginia rank as one of the four principal coke-producing states. Prior to 1895, there were only two coke-making establishments in Virginia, with a production of less than 200,000 tons per year. The number of establishments increased to seven in 1901, and the total number of coke ovens increased from 832 in 1896, to 2,775 in 1901, with a total production of more than 900,000 short tons. Construction and development work progressed rapidly during 1902, the number of establishments was doubled, and, at the close of the year, 2,974 ovens were built and 1,208 were building, with the production increased 1,124,572 short tons.

In 1903, two more establishments were added, making the total number 16, with a total of 4,251 ovens, and the production further increased to 1,176,439 short tons. In 1904, there was an increase of 94 completed ovens, the number of establishments remaining the same as in 1903, while the production declined to 1,101,716 short tons. Two establishments having a total of 107 ovens were reported idle during the year 1904. One of these was the Newton-Chambers ovens at Pocahontas in Tazewell county.

The production of coke in 1905 amounted to 1,499,481 short tons, valued at $2,869,452, as compared with 1,101,716 short tons, valued at $1,772,717 in 1904, an increase of 36.1 per cent. in quantity, and 62 per cent. in value. The number of ovens increased from 4,345 in 1904 to 4,549 in 1905, an increase of 204.

There were 18 establishments in 1906, an increase of two over 1905, and the total number of ovens increased from 4,549 to 4,641 in 1906. The production increased from 1,499,481 short tons in 1905, valued at $2,869,452, to 1,577,659 short tons, valued at $3,611,659. The value of coke at the ovens increased from $1.91 per ton to $2.29.

In 1907, the production of coke decreased from 1,577,659 short tons in 1906, to 1,545,280 in 1907, a loss of 32,379 tons or 2.1 per cent. Owing, however, to better prices which prevailed in 1907, the value of the coke produced increased from $3,611,659 in 1906 to $3,765,733 in 1907, an increase of $154,074 or 4.3 per cent. There were 19 establishments in 1907, an increase of one over 1906, and the number of ovens increased from 4,641 to 5,333 in 1907.

The monetary troubles in the latter part of 1907 very seriously effected the coke industry in the State during 1908. There was a decrease in the amount of coke produced from 1,545,280 short tons in 1907 to 1,162,051 tons in 1908, a loss of 383,229 tons or 24.8 per cent.; and, in value, a decrease from $3,765,733 in 1907 to $2,121,980 in 1908, a loss of $1,643,753 or 43.65 per cent. The value of coke at the ovens decreased from $2.44 per ton in 1907 to $1.83 in 1908. The number of establishments (19) remained the same as for 1907, but there was a decrease in ovens from 5,333 to 4,853 in 1908.

The principal part of the coke production in Virginia during the last few years has been from the development of the coal fields in Wise county, on the Clinch Valley division of the Norfolk and Western Railway. In 1907, the total production from Wise county amounted to 1,353,225 short tons, or 87.6 per cent. of the total production for the State, and in 1908, it amounted to 1,738,079 tons, or 81.9 per cent. of the total production.

There are given in the table below the statistics of the manufacture of coke in Virginia in 1908, by counties.

Statistics of the manufacture of Coke in Virginia in 1908, by counties.

County	Ovens		Coal used (short tons)	Value of coal used	Coke produced (short tons)	Total value of coke
	Built	Building				
Alleghany......	216	158	308,061	$ 314,055	189,354	$ 383,901
Lee............	207					
Tazewell.......	900					
Wise...........	3,530	....	1,477,220	1,189,392	972,697	1,738,079
Totals......	4,853	158	1,785,281	$1,503,447	1,162,051	$2,121,980

In the subjoined table are shown the statistics of the manufacture of coke in Virginia in 1883, when the first operations were begun, in 1890, 1900, and from 1903 to 1908, inclusive.

Statistics of the manufacture of Coke in Virginia, 1883-1908.

Year	Establishments	Ovens		Coal used (short tons)	Coke produced (short tons)	Total value of coke at ovens	Value of coke at ovens, per ton	Yield of coal in coke (per cent.)
		Built	Building					
1883	1	200	0	39,000	25,340	$ 44,345	$1.75	65
1890	2	550	250	251,683	165,847	278,724	1.68	66
1900	7	[a]2,331	300	1,083,827	685,156	1,464,556	2.14	63.2
1903	16	[a]4,251	142	1,860,225	1,176,439	2,724,047	2.32	63.2
1904	16	[a]4,345	68	1,636,905	1,101,716	1,772,717	1.61	67.3
1905	16	[a]4,549	0	2,184,369	1,499,481	2,869,452	1.91	68.6
1906	18	[a]4,641	695	2,296,227	1,577,659	3,611,659	2.29	68.7
1907	19	[a]5,333	50	2,264,720	1,545,280	3,765,733	2.44	68.2
1908	19	4,853	158	1,785,281	1,162,051	2,121,980	1.83	65

[a] Includes 56 Newton-Chambers by-product ovens.

All the coal used in coke-making in Virginia up to 1895 was unwashed. Washing of slack coal began in 1896, and in 1898 the amount of washed slack coal used amounted to 210,000 short tons. All the coal used in the manufacture of coke in the State during 1908 was unwashed. Of the 1,785,281 short tons used, 1,438,754 tons were run-of-mine and 346,527 tons were slack. The character of the coal used in coke-making in Virginia during 1890, 1900, and from 1903 to 1908, inclusive, is shown in the table below.

Character of coal used in the manufacture of coke in Virginia, 1890-1908, in short tons.

Year	Run-of-Mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	98,215	0	153,468	0	251,683
1900	620,207	0	463,620	0	1,083,827
1903	857,332	0	1,002,893	0	1,860,225
1904	1,213,226	44,222	379,457	0	1,636,905
1905	1,096,656	0	1,087,713	0	2,184,369
1906	1,014,299	228,347	1,053,581	0	2,296,227
1907	1,271,518	0	993,202	0	2,264,720
1908	1,438,754	0	346,527	0	1,785,281

With the activity shown in the development of coal properties in the last few years in the southwest Virginia counties, particularly in Wise and Lee, there should follow in the near future a greatly increased coke production in the State.

CLAYS AND CLAY PRODUCTS

Virginia contains a variety of clays widely distributed and occurring at various geological horizons. They are found abundantly distributed throughout the Coastal Plain, Crystalline, and Mountain provinces of the State, and are adapted to a wide range of uses. Many of the deposits remain undeveloped, because they have not yet been investigated, and little is known regarding them. The only ones which have been systematically studied are those of the Coastal Plain or Tidewater region.

The clays of Virginia are suitable for many economic purposes, and can be divided into two groups, namely, residual and sedimentary. The residual clays have been formed by the weathering of rocks, involving processes of disintegration and decomposition. As a result of this, we find the residual clays overlying the parent rocks from which they were derived, forming deposits of variable thickness, depending partly on the depth to which the rocks have been changed, and partly on the amount of erosion they have suffered since their formation. Residual clays predominate in the belt (Piedmont region) underlain by the crystalline rocks, such as granites, gneisses, schists, etc., and have wide distribution west of the Blue Ridge. They are usually quite ferruginous and, therefore, red-burning. Their main use is for the manufacture of brick and drain tile, and some of the smoother deposits have been employed for making smoking pipes, notably those of Powhatan county.

The decomposition of pegmatite dikes in many of the Piedmont counties has yielded clays of high grade, free from iron, and sometimes sufficiently white to be used for the manufacture of white-ware products. Deposits of this type, known as kaolin, have been found in Henry, Nelson, Patrick, Mecklenburg, Campbell, Amherst, Hanover, and other counties in the Piedmont region.

The sedimentary clays represent deposits which have been laid down under water, one layer on another, the materials composing them consisting of the products of rock decay, which have been removed by erosion from the land surface, and washed down into the lakes or seas, where they have finally settled. These are abundant in both the Coastal Plain province, where they are usually of unconsolidated character, and west of the Blue Ridge, in which region they are largely of a hard and shaly nature. They are widely distributed geologically, and the geological distribution agrees somewhat closely also with the geographical range.

The Coastal Plain clays which have thus far proved to be of marked value to the clay-worker, occur in Eocene and Miocene beds of the Tertiary, and the Pleistocene of the Quaternary. The Eocene clays are best developed in the region south of Stafford Courthouse, where they form promising outcrops, but have not yet been developed. The Miocene clays are best known south of Richmond, in the vicinity of Curle's Neck, and Bermuda Hundred. This same formation also carries extensive beds of diatomaceous earth or clay, which is well exposed at Richmond and along the Rappahannock river. The Pleistocene clays occur as more or less basin-shaped deposits, widely scattered over the Coastal Plain region, and rest on top of the other formations.

Nearly all of the clay deposits noted in the Coastal Plain region, whatever their geological age, are of lenticular or lens-shaped character. The majority of them are red-burning, while only a few are buff-burning. No white-burning clays have thus far been found; but even though they lack in variety, so far as their color-burning qualities are concerned, it is probable that their possible uses are more numerous than is now supposed.

The results of a study of the Virginia Coastal Plain clays, including physical tests and chemical analyses, by Professor Heinrich Ries, in 1905, are embodied in the table opposite this page.

West of the Blue Ridge, in the Mountain province, shales probably suitable for brick-making have wide distribution, ranging in age from Cambro-Ordovician to Carboniferous. Many of these shale deposits will doubtless prove available for the manufacture of vitrified brick.

The abundant deposits of Virginia clays are only partially utilized at present, but, after their thorough investigation by the State Geological Survey and their uses better made known, they will be much more extensively employed and the industry greatly enlarged or expanded.

PHYSICAL TESTS AND CHEMICAL ANALYSES OF THE COASTAL PLAIN CLAYS IN VIRGINIA

Laboratory No.	Color	LOCALITY	Per ct. water required for mixing	Slaking	Plasticity	Grit	Per cent. air shrinkage	Average Tensile strength pounds per square inch	Cone 010			Cone 05			Cone 03			Cone 1			Cone 3			Cone 5			Cone 8			Chemical Composition										
									Fire shrinkage	Color	% Absorption	Fire shrinkage	Color	% Absorption	Fire shrinkage	Color	% Absorption	Fire shrinkage	Color	% Absorption	Fire shrinkage	Color	% Absorption	Fire shrinkage	Color	% Absorption	Fire shrinkage	Color	% Absorption	Loss on Ignition	Silica, SiO_2	Titanium Oxide TiO_2	Ferric oxide Fe_2O_3	Alumina, Al_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O	Total fluxes	Laboratory No.
1300	Yel. buff	Brick mixture, Maynard & Powers, Richmond	20.9	Mody. fast	Good	Fine	6.4	89.6	.0	Lt. red	17.40	1.6	Lt. red	15.08	1.6	Lt. red	14.06	5.	Red	7.1	6.3	Dk. red	4.04	6.6	Gr. br'n	1.4	6.3	Red br'n	1.29	4.61	71.50	1.44	4.78	13.86	.56	.11	2.29	0.81	8.50	1300
1302	Yel. buff	Fort Lee	24.2	Mody. fast	Good	Little	8.6	60.6	.0	Lt. red	20.2	1.6	Lt. red	17.6	4.	Lt. red	14.06	6.3	Lt. red	7.5	7.	Lt. red	5.9	8.3	Dk. red	2.6	7.3	Deep br.	1.10	5.52	69.55	1.06	6.05	15.79	Tr'ce	.08	1.54	0.38	8.05	1302
1305	Gray blk.	Two miles south of Chester	25.3	Fast	Low	Some	9.3	177.3	.0	Lt. red	18.2	1.3	Lt. red	14.2	1.6	M. red	12.	2.3	M. red	7.54	Vis.	Dk. red	7.65	Vis.	Dk. red	Fus'd	.0	....	......	4.41	69.74	.06	6. *	12.64	1.46	1.18	2.54	0.92	13.15	1305
1306	Yel. buff	One mile northwest of Bermuda Hundred	29.7	Fast	Good	Very fine	8.6	148.8	.3	Lt. red	22.04	5.7	Lt. red	12.9	7.	Lt. red	8.7	10.7	Dk. red	.12	10.3	Dk. red	.11	4.6	Gray	2.11	6.6	Dk. red	1.39	5.32	61.83	.08	6.85	21.26	.38	.78	2.44	1.01	11.46	1306
1307	Yel. buff	Keeler's yard, Broadway, on Appomattox River	24.6	Slow	Good	Very little	9.0	138.1	.3	Lt. red	17.9	5.0	Lt. red	10.40	6.3	Lt. red	7.3	8.	Red	1.7	9.3	Dk. red	1.8	7.	Red gray	1.7	7.6	Red br'n	.50	6.67	59.59	.12	8.07	21.10	.20	.76	2.38	1.06	12.47	1307
1311	Yel. buff	Sturgeon Point	23.1	Mody. fast	Good	Fine	7.6	122.6	.0	Lt. red	16.8	2.3	Lt. red	11.9	3.	Red	8.2	5.6	Red	3.9	7.	Dk. red	1.9	5.3	Dk. red	1.5	5.6	Dk. red	1.07	4.53	68.60	.16	6.41	16.11	.75	.32	2.35	.71	10.54	1311
1312	Gray	Oldfield	20.3	Slow	Good	Much	7.6	111.5	.0	Pink buff	16.3	1.6	Pink buff	15.04	2.	Pink buff	13.6	3.6	Yel. red	7.2	6.	Pk. buff	3.9	6.6	Gray	1.08	7.3	Drab	1.57	2.81	73.84	1.22	3.39	15.08	.62	.12	2.17	.71	7.01	1312
1313	Buff	Oldfield	23.1	Mody. fast	Good	Little	8.6	191.0	.3	Lt. red	17.5	1.6	Lt. red	14.8	4.	Lt. red	9.6	6.3	M. red	5.5	7.	M. red	4.9	7.6	Dk. gray	1.68	5.	Drab	1.10	5.34	68.97	1.28	4.22	16.51	.44	.05	2.59	.56	7.86	1313
1314	Yel. buff	Ball property six miles southeast of Richmond	20.9	Mody. fast	Good	Little	7.4	134.8	.0	Lt. red	17.7	4.7	Lt. red	10.1	6.	Lt. red	7.02	8.3	Red	1.5	7.6	Dk. red	.4	3.	Dk.r.br.	2.6	s.s.	Dk. red	1.02	4.10	65.97	1.04	6.74	17.38	1.16	.17	2.46	.93	11.46	1314
1315	Yel. buff		23.1	Mody. fast	Good	Little	7.3	126.7	.0	Lt. red	19.5	3.	Lt. red	14.8	4.3	Lt. red	13.1	9.0	M. red	2.5	8.6	Dk. red	1.01	7.	Gray	.7	7.	Red br'n	.55	5.41	63.82	Trce	6.32	20.44	.22	.11	2.72	.93	10.30	1315
1316	Lt. gray		24.2	Mody. fast	Excellent	Little	8.6	135.1	.0	Pk. cream	16.03	4.3	Pink buff	9.2	5.	Buff	4.7	6.5	Gray buff	.09	7.	Gray buff	.07	7.	Drab	.14	s.s.	Drab	.90	4.82	66.01	.50	3.59	20.77	.92	.11	2.52	.74	7.88	1316
1322	Br. buff	Impure diatomaceous earth Richmond	31.6	Fast	Lean	Some	13.		.6	Lt. red	14.62	.6	Lt. red	13.6	2.	Lt. red	12.42	3.	Lt. br'n	9.1	3.3	Red br'n	6.9	5.	Red gray	5.06	2.	Brown	2.04	5.21	70.42	.44	5.17	15.15	.14	.79	2.24	.39	8.73	1322
1323	Buff		34.6	Fast	Lean	Some	14.		.6	Lt. red	14.9	2.3	Lt. red	10.9	3.3	Lt. red	9.	5.	M. red	4.16	6.	M. red	2.30	6.	Red gray	1.70	5.6	Red gray	1.09	6.39	63.17	.88	6.32	19.30	.06	.69	2.45	.69	10.21	1323
1324	Yel. buff	W. J. Ready's yard, Manchester, by Richmond	20.3	Mody. fast	Good	Sandy	7.	93.7	s. s.	Lt. red	15.5	1.3	M. red	12.9	1.6	M. red	11.4	3.7	Dk. red	6.2	5.3	Dk. red	3.4	5.	Dk. red	1.4	5.5	Dr.r.br'n	.19	4.03	73.38	N'ne	5.53	13.53	.58	.14	2.32	.47	9.04	1324
1325	Brown		20.3	Mody. fast	Good	Much	6.	132.	s. s.	Lt. red	17.5	2.	Lt. red	16.8	2.6	M. red	12.07	3.6	Dk. red	9.8	4.	Dk. red	8.7	5.	Dk. red	6.29	Vis.	Red br'n	1.47	4.85	69.43	N'ne	6.70	14.79	.57	.63	2.26	.71	10.87	1325
1326	Br. buff		18.7	Fast	Fair	Sandy	6.	99.	s. s.	Lt. red	16.4	.6	M. red	15.1	1.	M. red	14.4	2.	M. red	10.3	3.	Dk. red	8.2	5.6	Red	1.6	.6	Red br'n	1.00	3.65	72.61	.44	5.61	13.08	.96	.23	2.45	.93	10.18	1326
1330	Gray	Williamsburg road, near Stagg's Mill, Richmond	27.8	Slow	High	Some	12.6	300.9	1.	Pink	14.4	3.	Pink	8.9	5.	Lt. red	5.65	7.6	Red br'n	1.07	7.6	Dk. br'n	.08	2.	Gray	2.4	3.	Drab	1.56	5.29	63.06	.04	6.26	20.90	.16	.45	3.13	.68	10.68	1330
1331	Br. buff	Turner's yard, near Petersburg	23.1	Slow	Excellent	Little	8.	135.5	.3	Lt. red	17.09	2.	Lt. red	15.30	3.6	Lt. red	11.80	4.6	M. red	7.8	5.	M. red	8.7	7.6	Dk. red	3.	6.3	Dk. red	1.30	7.25	61.35	.06	7.10	19.70	.67	.34	2.38	1.11	11.60	1331
1333	Lt. brown	Wood's yard, near Emporia	24.0	Slow	Good	Little	8.6	132.4	.3	Lt. red	16.30	1.	Lt. red	13.70	2.7	Lt. red	11.90	3.	M. red	11.05	3.6	Dk. red	9.9	4.3	Dk. red	6.20	6.	Dk. red	1.08	6.09	67.14	N'ne	6.21	16.18	1.19	.11	1.95	1.10	10.56	1333
1334	Lt. brown	Clays showing variable character of upper bed at Sturgeon Point	24.2	Mody. fast	Fair	Sandy	8.3	144.2	.3	Lt. red	17.7	1.6	Lt. red	14.7	3.0	Lt. red	12.1	4.3	M. red	8.2	5.	Dk. red	6.6	4.6	Dk.r.gray	5.	5.	Red br'n	.21	5.07	69.75	.06	4.67	17.13	.53	.31	1.89	.56	7.96	1334
1335	Gray		18.7	Fast	Fair	Much	6.	105.1	.0	Pink	15.7	.3	Pink	14.5	1.3	Lt. red	12.2	1.3	Lt. red	10.3	2.6	Mot. red	9.3	2.3	Lt. red	7.86	3.6	Lt. br'n	.31	3.03	74.55	.22	3.07	15.43	.43	.65	1.42	1.16	6.73	1335
1336	Gray		18.7	Fast	Low	Sandy	5.	79.8	s. s.	Pink	15.08	s. s.	Lt. red	14.4	.0	Lt. red	13.9	.0	M. red	12.90	7.	Lt. red	12.3	.0	Dir.lt.red	10.91	1.3	Lt. br'n	6.50	3.24	77.78	.20	3.05	12.84	.40	.29	1.69	.44	5.87	1336
1336a	Gray	Clay from river level, Sturgeon Point	30.2	Mody. fast	Fair	Little	8.	118.7	.3	Blu'h. red	20.54	2.	Lt. red	15.9	5.3	Lt. red	9.81	8.3	Dk. red	2.80	.0	Dk. red	1.5	8.6	Dk. red	.15	7.	Dk. red	.04	7.49	61.21	Tr'ce	5.81	20.82	.57	.75	2.57	.73	10.43	1336 A
1339	Br. buff	City Point	20.3	Slow	Excellent	Much	7.6	155.	.6	Lt. red	17.2	3.3	Lt. red	11.5	4.	Lt. red	10.05	6.	M. red	4.6	6.3	Dk. red	2.7	6.6	Dk. red	1.3	6.6	Dk. red	1.52	7.76	61.06	.16	7.03	19.61	.77	.09	2.34	1.01	11.24	1339
1343	Gray	Standard Brick Co., south of Suffolk	22.	Slow	Excellent	Much	8.6	144.6	s. s.	Pinkish	14.6	1.6	Pinkish	13.6	1.6	Buff	12.6	1.6	Lt. red	10.9	2.3	Lt. red	9.7	3.	Lt.yellow	7.01	3.3	Lt. br'n	3.60	5.06	75.79	Tr'ce	3.17	14.85	.04	.08	.75	.22	4.26	1343
1344	Drab	Blue clay, Suffolk Clay Co., Suffolk	31.9	Slow	Excellent	Little	11.6	143.8	1.3	Pink	16.9	4.	Pink	8.87	5.6	Lt. red	6.11	7.	Lt. br'n	1.50	7.6	Drab	.20	B'd vitri	Lt. gray	Bey'nd vitri	.0	Drab	......	6.66	64.39	.08	4.40	20.49	.17	.91	2.31	.54	8.33	1344
1345	Buff	Brick mixture, Suffolk Clay Co., Suffolk	26.4	Slow	Good	Little	10.3	142.5	.6	Pink	15.4	3.	Lt. red	10.6	3.6	M. red	7.5	6.6	M. red	2.6	7.3	Dk. red	1.04	7.	Gray	.60	5.	Red drab	.02	5.98	65.55	1.95	5.29	18.13	.39	.51	1.82	.33	8.34	1345
1350	Pink	Eocene clays from between Stafford C. H. and Fredericksburg	36.3	Mody. fast	Crumbly	Little	9.3	115.3	.6	Lt. red	28.2	2.6	Pink	23.1	3.6	Lt. red	14.20	7.	Lt. red	12.06	9.	Lt. red	7.91	10.3	Red br'n	3 50	10.3	Red br'n	3.74	8.63	51.12	.47	10.70	26.14	.10	.25	1.78	.77	12.87	1350
1352	White		35.2	Mody. fast	Good	Little	8.6	113.7	.6	Pk. white	25.4	.0	....	....	2.6	Cream	19.6	5.	Cream	13.2	6.3	Lt. yel.	13.1	7.6	Yel. buff	8.30	10.	Drab	2.49	8.44	57.26	.14	3.10	28.97	.04	.19	1.40	.42	5.15	1352
1353	Yel. br'n	Between Milford and Bowling Green	27.5	Mody. fast	Good	Little	11.	193.6	.3	Lt. red	16.6	2.	Lt. red	13.3	2.	Red br'n	11.79	4.	M. red	9.70	4.3	Dk. red	5.32	5.	Red br'n	2.09	5.	Red br'n	2.02	5.09	69.00	.10	6.72	15.58	.06	.15	2.34	.91	10.18	1353
1354	Gr'n gray	One mile south of Layton	24.2	Slow	Low	Much	6.	41.2	s. s.	Lt. red	26.80	.0	Lt. red	27.5	.3	Lt. red	27.77	1.	Lt. red	27.	1.6	Red	25.5	2.	Lt. br'n	27.9	2.3	Red	24.79	3.55	85.72	.06	1.74	5.83	1.01	.11	1.31	.64	4.81	1354
1356	Light red	Red clay, northwest of Fredericksburg	33.0	Fast	Good	Little	9.6	79.9	.6	Lt. red	28.01	4.	Lt. red	21.70	6.	M. red	15.40	11.	Dk. red	4.08	12.3	Dk. red	1.4	12.6	Dk. red	.18	13.3	Dk. red	.02	6.00	55.33	.81	9 02	25.69	.22	.08	2.57	.25	12.14	1356
1358	Light red	Diatomaceous earth, one mile south of Layton	23.1	Fast	Low	Little	10.3	29.4	.6	Lt. red	21.73	.6	Lt. red	20.70	2.3	Lt. red	15.88	5.6	Pink	11.3	5.6	Red gray	9.5	6	Lt. br'n	5.4	6.3	Lt. br'n	2.57	3.66	78.82	.33	5.42	9.24	.04	.12	1.51	.81	7.90	1358
1362	Lt. brown	Pleistocene clay, Wilmont	19.2	Mody. fast	Good	Some	7.3	130.8	.0	Lt. red	12.84	.0	....	12.0	1.	Lt. red	10.30	2.6	Lt. red	8.5	2.3	Lt. br'n	6.1	3.	Lt. red	5.9	4.3	Br. red	2.03	4.74	71.60	1.88	4.65	13.18	.42	.66	1.58	1.23	8.54	1362
1363	White	Diatom earth, Wilmont	62.4	Fast	Low	Some	3.6	34.4	1.3	Yell'wish	50.96	1.6	Lt. pink	48.4	1.	Lt. pink	44.00	4.6	Pk.cream	41.4	4.6	Yellow	40.9	5.3	Yellow	38.3	5.6	Yel. br'n	32.32	3.40	82.85	1.09	2.34	6.76	.35	1.06	1.07	.99	5.81	1363
1365	Buff	Clay from "House" bank southeast of Wilmont	22.0	Mody. fast	Good	Much	7.6	87.1	s. s.	Pk. cream	15.2	.0	Pk. cream	14.4	.3	Pk. cream	14.01	1.3	Yel. br'n	12.22	1.6	Br. yel.	10.72	1.3	Red yel.	11.2	2.3	Red yel.	9.87	4.59	77.28	.06	2.42	13.01	N'ne	.70	1.22	.68	5.02	1365
1367	White	Sandy clay, Occupacia P. O.	26 4	Fast	Fair	Sandy	8.6	54.2	.0	Lt. red	29.89	.6	Lt. red	28.3	1.6	Lt. red	27.72	2.	Pink	23.34	2.3	Lt. red	23.7	2.6	Yel. br'n	21.05	5.	Brown	19.	3.06	84.64	.24	2.59	7.73	.10	.17	1.12	.32	4.30	1367

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*FeO, 1 per cent.

s. s. Slightly swelled.

The chemical analyses in this table were made by Messrs. J. R. Eoff, Jr., and J. H. Gibboney.

In 1908, the total value of all clay products manufactured in Virginia, including the value of kaolin, fire clay, and miscellaneous clay mined and sold in the State, amounted to $1,540,157. Compared with the value ($1,611,335) of the 1907 production, there is a decrease of $71,178 or 4.6 per cent.

The following table gives the statistics of clay products in Virginia from 1903 to 1908, inclusive, and is of interest to those who desire to know something of the growth of the industry in the State. The item "Miscellaneous" in the table includes all products not otherwise specified (fire brick, sewer pipe, drain tile, fancy or ornamental brick, kaolin, and pottery products), and those which could not be published separately without disclosing individual returns.

Clay Products in Virginia from 1903 to 1908, inclusive.

Product	1903	1904	1905
Brick:			
Common—			
Quantity	189,891,000	203,484,000	237,161,000
Value	$1,245,861.00	$1,292,558.00	$1,572,442.00
Average per thousand	$6.56	$6.35	$6.63
Vitrified—			
Quantity	(a)	(a)	(a)
Value	(a)	(a)	(a)
Average per thousand	$8.92	$10.46	$10.80
Front—			
Quantity	18,866,000	21,077,000	22,155,000
Value	$303,431.00	$344,891.00	$352,297.00
Average per thousand	$16.08	$16.36	$15.90
Fancy or ornamental. Value	$27,330.00	$28,576.00	$20,363.00
Fire. Value	(a)	(a)	(a)
Fire. Value	(a)	(a)	(a)
Drain tile. Value	$4,750.00	$5,673.00	$4,500.00
Pottery:			
Earthenware and stoneware. Value	(a)	(a)	....
Porcelain electrical supplies. Value	....	(a)	(b)
Miscellaneous. Value	$91,974.00	$64,694.00	$44,976.00
Total value	$1,673,346.00	$1,736,392.00	$1,994,578.00
Number of operating firms reporting	100	99	94

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[a] Included in miscellaneous.

[b] The value of pottery products for Virginia for 1905, 1906, 1907, and 1908 are included in miscellaneous.

Clay Products in Virginia from 1903 to 1908, inclusive.—Con.

Product	1906	1907	1908
Brick:			
Common—			
Quantity	232,697,000	197,052,000	185,738,000
Value	$1,536,312.00	$1,285,374.00	$1,219,946.00
Average per thousand	$6.60	$6.52	$6.57
Vitrified—			
Quantity	....	....	....
Value	....	....	....
Average per thousand	....	....	....
Front—			
Quantity	25,385,000	19,989,000	17,858,000
Value	$392,130.00	$290,411.00	$246,623.00
Average per thousand	$15.45	$14.53	$13.81
Fancy or ornamental. Value	(a)	(a)	(a)
Fire. Value	$21,110.00	(a)	(a)
Drain tile. Value	$4,805.00	$6,250.00	$7,100.00
Pottery:			
Earthenware and stoneware. Value	....	....	....
Porcelain electrical supplies. Value	(b)	(b)	(b)
Miscellaneous. Value	$11,721.00	$29,300.00	$66,488.00
Total value	$1,966,078.00	$1,611,335.00	$1,540,157.00
Number of operating firms reporting	91	87	82

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[a] Included in miscellaneous.

[b] The value of pottery products for Virginia for 1905, 1906, 1907, and 1908 are included in miscellaneous.

BRICK CLAYS

Clays suitable for the manufacture of common and front brick, particularly the former, are widely distributed throughout the State. In fact, nearly every county in Virginia contains clay suitable for the manufacture of common brick, and, in most cases, the deposits are of such character that common brick of the best quality can be made. The brick-yards can be located usually near railroad transportation, and fuel for burning the brick can be obtained, as a rule, at a minimum price. Virginia clays used in the manufacture of common brick are of two types, residual and sedimentary, discussed on page 65.

The total number of common and front brick manufactured in Virginia in 1908 was 203,596,000, valued at $1,466,569, as against 217,041,000, valued at $1,575,785 in 1907, a decrease of 13,445,000 in quantity and $111,216 in value. Of the 1908 production, 185,738,000 were common brick, valued at $1,219,946, and 17,858,000 front brick, valued at $246,623. The average value per thousand of the 1908 production was: Common brick $6.57, front brick $13.81.

The total value of fancy or ornamental brick and of fire brick produced in Virginia in 1908 was $20,011. There were 36 counties from which the total brick production was obtained. The quantity and the value of the different varieties of brick manufactured in Virginia in 1908 are given in the table on page 68.

In the following table are given the total number and value of the different varieties of brick manufactured in Virginia in 1908, by counties:

Production of Brick and Tile in Virginia in 1908, by counties.

County	Common Brick		Front Brick	
	Quantity Thousands	Value	Quantity Thousands	Value
Albemarle	1,500	$ 10,500		
Alexandria	64,324	451,338	15,807	$212,880
Augusta	899	7,436		
Carroll	600	3,500		
Charles City	3,500	23,766		
Chesterfield	10,610	58,895		
Halifax	1,414	8,450		
Henrico	30,453	212,683	400	5,775
James City	2,525	15,200		
Nansemond	13,185	75,226		
Pittsylvania	2,000	14,000		
Roanoke	11,618	61,040		
Rockingham	1,710	12,320		
Shenandoah	600	4,200		
Tazewell	2,341	14,522		
Warwick	1,750	13,000		
Other counties	36,709[a]	233,870[a]	1,651[b]	27,968[b]
Total value	185,738	$1,219,946	17,858	$246,623

[a] Includes Albemarle, Alleghany, Brunswick, Campbell, Caroline, Culpeper, Dinwiddie, Fairfax, Frederick, Henry, Isle of Wight, Lancaster, Norfolk, Nottoway, Orange, Princess Anne, Prince George, Rockbridge, Smyth, and Surry.

[b] Includes Augusta, Chesterfield, Halifax, Orange, and Powhatan.

FIRE CLAYS

Refractory clays are known to occur in many localities of the State, but they have not yet been investigated, and the production is small and variable. It is highly probable that the clayey members, including shales of the Carboniferous system of rocks, occurring west of the Blue Ridge and having the most extensive development in southwest Virginia, will prove of sufficient value for making vitrified wares. The Triassic shales associated with the coals of the Richmond basin have not proved of any value for the manufacture of clay products. Clays of the refractory type occur in a number of the Piedmont counties, and have been worked at several localities in some of these.

The production of fire clay during 1908 was small and is included under "Miscellaneous" in the table on page 68. In 1906, the total value of fire clay mined in Virginia was $21,110.

POTTERY CLAYS

The pottery industry in Virginia is a small but gradually growing one. The total value of pottery products made in Virginia in 1908 amounted to $37,777.

KAOLIN

The production of kaolin in Virginia has been derived almost entirely from the decomposed pegmatite dikes, which intersect the crystalline rocks of the Piedmont region. Deposits of this type have been worked in Amelia, Henry, and Nelson counties, and are known to occur but not developed in many other of the Piedmont counties. Of these, Henry is the principal producing county at present. At the Blue Ridge Kaolin Company's mines, near Oak Level in Henry county, the kaolin is mined by circular pits, and, before shipment to market, it is put through a washing process in order to free it from grains of sand, mica, and other mineral impurities, which are present in small quantities.

The following analyses give the composition of the crude (I) and washed (II) kaolin from this locality.

	I Per cent.	II Per cent.
Silica (SiO_2)	66.82	45.70
Alumina (Al_2O_3)	24.00	39.18
Ferric oxide (Fe_2O_3)	0.94	0.78
Lime (CaO)	0.28	0.44
Magnesia (MgO)	0.11	0.05
Potash (K_2O)	2.59	1.78
Soda (Na_2O)	0.16	0.20
Titanic oxide (TiO_2)	0.12	0.28
Water (H_2O)	5.52[a]	12.09[b]

[a] Includes 2.00 per cent of moisture.
[b] Includes 1.98 per cent. of moisture.

The production of kaolin in Virginia has been small, that of the year 1908 being included under "Miscellaneous" in the table on page 68.

LIME AND CEMENT

Lime and cement are obtained from limestone, which is described in discussing the limestone industry on pages 85 to 87, inclusive. Plants for their manufacture are scattered widely over western Virginia, where the raw material, admirably adapted to the manufacture of lime and cement, occurs in great abundance. Plants for the burning of lime are found in the majority of the counties west of the Blue Ridge, while at present the only mill for the manufacture of Portland cement is in Augusta county. Mills for the manufacture of natural cement are limited to Rockbridge and Botetourt counties.

The total value of lime and cement produced in Virginia during 1908 shows a substantial gain over that of 1907. The increasing demand for lime in the Southern states, chiefly for agricultural and building purposes, will probably mark a greater increase in Virginia's production during 1909. There was no reported production of natural cement in the State during 1908, the entire product being Portland cement from the plant at Fordwick, in Augusta county.

LIME

During recent years, lime-making in Virginia has been confined to the counties west of the Blue Ridge, where there are numerous plants engaged in the industry. There occur abundant limestones throughout this region admirably adapted to the making of lime. These range from very pure limestones to those high in magnesia. The former when burned or calcined yield "high limes" or "fat limes," while the latter produce "lean" or magnesian limes. Most of the lime made in Virginia belongs to the first class, and is especially valued by the builders and farmers.

The crystalline limestones of the Piedmont Plateau yield when calcined a good grade of lime. Formerly, numerous small kilns were operated within the limits of this region for the production of lime to supply only immediate local demands. In recent years, however, these have been abandoned, and at present no lime is burned from the Piedmont limestones.

The shell marls of the Coastal Plain region are dug and used locally, in the natural state, as fertilizer on the farming lands. These marls frequently form extensive deposits of considerable purity, and since they occur as loose incoherent material, and usually in a finely comminuted state, they can be easily dug and readily applied in the natural state to the soil.

The total production of lime in Virginia in 1908 was 107,209 short tons, valued at $424,374, a slight decrease over the production of 1907, which amounted to 115,155 short tons, valued at $447,307. The average price per ton in 1908 was $3.95 as against $3.89 in 1907. This production was distributed over eleven counties and twenty-eight producers. The counties producing lime in 1908 were Augusta, Botetourt, Frederick, Giles, Loudoun, Montgomery, Rockbridge, Rockingham, Shenandoah, Tazewell, and Warren.

The quantity and value of the annual production of lime from 1905 to 1908 are given in the accompanying table.

Quantity and value of Lime produced in Virginia, 1905-1908, in short tons.

Year	Quantity	Value	Average price per ton
1905	114,221	$396,434	$3.47
1906	104,468	382,083	3.66
1907	115,155	447,307	3.89
1908	107,209	424,374	3.95

There are given in the table below the production and value of lime in Virginia in 1908, by counties.

Production and value of lime in Virginia in 1908, by counties.

County	Production Short tons	Value
Botetourt	25,289	$106,194
Frederick	16,909	53,280
Loudoun	4,800	16,600
Montgomery	966	4,538
Rockbridge	6,880	28,218
Shenandoah	27,547	107,089
Warren	15,190	74,417
Other counties[a]	9,628	34,038
Total	107,209	$424,374

[a] Includes Augusta, Giles, Rockingham, and Tazewell.

In the table below is given the production of lime in Virginia in 1908, by uses.

Production of Lime in Virginia, in 1908, by uses, in short tons.

Use	Quantity	Value
Building lime	75,292	$313,720
Hydrated lime	(a)	....
Paper mills, etc	(a)	....
Fertilizer	16,698	56,036
Gas works	(a)	....
Tanneries	1,103	3,716
Dealers—uses not specified	5,894	19,832
Other purposes	326	1,040
Miscellaneous[b]	7,896	30,030
Total	107,209	$424,374

[a] Included under miscellaneous.
[b] Includes hydrated lime, paper-mill lime, and lime for gas works.

CEMENT

Although the cement industry may be said to be in its infancy in Virginia, yet the manufacture of this important economic product has been carried on for many years at one locality, and for a less time at another. Natural cement has been burned at Balcony Falls for over a half century. The demand for a cheap and trustworthy cement for use in the construction of masonry, locks, and walls on the James river canal, led to the discovery of the hydraulic properties of the rock used at this plant. Since that time a natural cement has been manufactured at this locality almost continuously, the James River Cement Company operating the plant at present. The rock used is a blue, argillaceous limestone of Lower Cambrian age, with an average thickness of 12 feet.

There is only one plant for the manufacture of Portland cement in Virginia in operation at present, namely, that of the Virginia Portland Cement Company at Craigsville, Augusta county. This plant started nine years ago with a capacity of 200,000 barrels. It now has a capacity of 1,250,000 barrels, and is selling the Old Dominion cement in the North as well as in the South. The materials used by this plant in the manufacture of Old Dominion cement are Lewistown limestone and shale.

Recently, two additional plants of large capacity have been granted charters for the manufacture of Portland cement in Tidewater (Coastal Plain) Virginia. These are the Norfolk Portland Cement Company's plant to be located near Norfolk, and the Jamestown Portland Cement Company's plant to be located at Yorktown, with an estimated daily output of 2,500 barrels of cement. The raw materials to be used by these plants for the manufacture of Portland cement will be the Miocene marls and clays of the immediate area.

Virginia possesses an abundance of raw materials from which cement can be made—an economic resource which will prove of great value. The Appalachian Valley and the various mountains and valleys westward, an area 350 or more miles long and averaging 50 miles in width, contains limestones and shales equal in value and abundance to those of any other region. The State Geological Survey has just issued a valuable report[a] on the Cement Materials west of the Blue Ridge. This report is based on several seasons of careful investigations in the field, and contains an unusually large number of chemical analyses made of the limestones and shales from all parts of the region.

Four prominent sources of cement material obtain in Western Virginia. Named in geologic order, these are:

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[a] Bassler, R. S., Virginia Geological Survey, Bulletin No. [illegible]-A, 1909.

4. Greenbrier (Mississippian) limestone.
3. Lewistown (Helderbergian) limestone.
2. Ordovician (Trenton, etc.) limestones and shales.
1. Cambrian—impure limestone and shale.

Of these, the limestones and shales of Ordovician age are the most promising on account of their abundance, widespread distribution, and usually favorable chemical composition. The Lewistown limestone is now used in the manufacture of Portland cement at Craigsville, Augusta county, and the Greenbrier limestone will probably become an important source of cement material in southwestern Virginia.

The most important cement materials of western Virginia are found in the pure and argillaceous limestones of Cambrian and Ordovician age, and in the calcareous and argillaceous phases of the Ordovician shales. These shales and limestones have a wider distribution and are usually more accessible than other cement rock horizons of the State, such as the Lewistown of Helderbergian age, and the Mississippian or Subcarboniferous (Greenbrier) limestone. In general the entire Valley of Virginia is underlain by the Cambrian and Ordovician limestones, while the shales usually outcrop along the base of the mountains bounding it. In a similar manner, many of the valleys west of the Great Valley show these limestones and shales, higher formations occurring on the separating ridges.

Three classes or groups of hydraulic cement[a] are recognized, and materials for their manufacture occur in Virginia. Named in the order of their importance, these are: (1) Portland cement, (2) Natural cement, and (3) Puzzolan cement.

In the manufacture of Portland cement, a finely ground mixture containing lime, silica, alumina, and iron oxide, in exactly determined proportions, is burnt at a temperature approaching 3,000° F. This burning produces a semi-fused mass called "clinker" which, as a last step in the process of manufacture, must be finely ground. The theoretical mixture employed for burning consists of 75 per cent. calcium carbonate, 20 per cent. iron, alumina, and silica, and 5 per cent. allowed for magnesium carbonate and other substances. This ideal composition is seldom realized in nature and, as a rule, an artificial combination is made by mixing limestone or marl with clay or shale. In this case, one part of the clayey materials is generally added to three parts of pure limestone.

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[a] Bassler, R. S., Virginia Geological Survey, Bulletin No. II–A, 1909. Eckel, E. C, Cements, Limes, and Plasters: Their Materials, Manufacture, and Properties. John Wiley and Sons, New York, 1907.

The raw material from which natural cement is made is an argillaceous limestone carrying from 13 to 35 per cent. of clayey material, of which about 10 to 22 per cent. is silica, while alumina and iron oxide together may vary from 4 to 16 per cent. Unlike Portland cement rock, the percentage of magnesium carbonate may run high, the reason for this being that in natural cements the magnesia and lime are regarded as interchangeable. The hydraulic properties do not depend upon the percentage of lime but upon the clayey materials, which are the important factors to consider in the rock analysis.

Limestones having a composition within the limits just indicated are more or less abundant at several horizons in western Virginia, but probably the only one which will meet all the requirements and prove of economic importance is the argillaceous magnesian limestone of the lower part of the Shenandoah group. This rock, although often very similar in lithologic characters to the dolomitic limestone found higher in the Shenandoah group, can be recognized as containing argillaceous matter by the clayey odor given forth when breathed upon.

These limestones (Sherwood) and shales (Buena Vista) form the source of the rock used by the James River Cement Works, near Balcony Falls, Virginia, for making natural cement. These strata are found at various points along the eastern side of the Appalachian Valley in Virginia, so that a considerable supply of the necessary materials should be available.

The erection and operation of Portland cement plants, such as are now proposed in Tidewater Virginia, will have a stimulating influence on the entire industrial activity of the State.

SAND AND GRAVEL

The value of the production of sand and gravel in Virginia during 1908 was $119,095, as compared with $123,812 in 1907, a decrease in value of $4,717. These figures do not represent the total production of sand and gravel in Virginia, as large quantities are produced and utilized each year in the manufacture of brick, and in railway, highway, and sidewalk construction, etc., of which no record of the quantity used is kept and no returns are made to the office of the State Survey. Much the largest proportion of sand used in the State, for which returns are made, is for building and molding. In 1908, there were 33 producers of sand and gravel operating in 20 counties. The following table shows the details of the industry, and the comparative quantities and values in 1905 to 1908, inclusive.

Production of Sand and Gravel in Virginia, 1905-1908, by uses, in short tons.

	1905		1906		1907		1908	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Sand—								
Glass	....	....	....	....	1,246	$ 4,535	....	....
Molding	61,246	$ 37,899	26,654	$ 15,466	50,627	30,377	47,888	$ 22,568
Building	244,572	96,248	272,396	91,265	158,715	67,160	139,742	61,378
Fire	810	405	1,000	500	....	....	....	....
Engine	4,775	3,580	4,370	1,970	10,239	4,603	6,651	2,860
Furnace	4,212	2,665	21,376	8,028	10,059	4,227	11,295	5,500
Other	250	330	8,602	4,072	24,334	9,958	670	325
Gravel	35,250	13,453	780	650	13,002	2,952	242,988	26,464
Total	351,115	$154,580	335,178	$121,951	268,222	$123,812	449,234	$119,095

There is given in the table below the production of sand and gravel in Virginia in 1908, by counties.

Production of Sand and Gravel in Virginia in 1908, by counties.

County	Sand Value	Gravel Value
Giles	$ 8,287	
Henrico	20,678	(a)
New Kent	2,471	
Pulaski	2,975	
Rockingham	1,690	
Roanoke	6,320	
Other counties[b]	50,210	26,464[c]
Total	$92,631	$26,464

[a] Included under other counties.

[b] Includes Augusta, Alexandria, Alleghany, Campbell, Charles City, Caroline, Dinwiddie, Norfolk, Princess Anne, Shenandoah, Spottsylvania, Wise, and Wythe.

[c] Includes Augusta, Henrico, Alexandria, Spottsylvania, and Shenandoah.

SAND-LIME BRICK

The term sand-lime brick is used "to cover all brick made by mixing sand or gravel with a relatively small percentage of slaked lime, pressing the mixture into form in a brick mold, and drying and hardening the product either by sun heat or artificial methods."[a]

The manufacture of sand-lime brick in Virginia, begun only a few years ago, has constantly increased in production. The total number of sand-lime brick produced in 1908 was 6,181,000 brick, valued at $36,934, of which 6,123,000 were common brick valued at $36,184. This production was made by four counties: Montgomery, Northampton, Princess Anne, and Wise.

STONE

The production of stone has been an important industry in the State for many years, and the product of some varieties, especially granite, has been used in many notable structures. The rocks of Virginia include a large variety and abundance of excellent stone suitable for building, decorative, and other purposes. These have wide distribution over the Crystalline and Mountain provinces, comprising in the former, granite, gneiss, and schist, trappean rocks in part known to the trade as black granites, slate, quartzite and sandstone, limestone and marble; and in the latter, sandstone, limestone, and marble.

The stone industry is the fourth in importance among those based upon the mineral wealth of the State, being surpassed only by the coal, clay products, and iron ores. The value of the annual production of stone in Virginia from 1900 to 1908, inclusive, is given in the accompanying table.

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[a] Eckel, E. C., Cements, Limes, and Plasters: Their Materials, Manufacture, and Properties. John Wiley and Sons, New York, 1907, p. 130.

Value of the annual production of Stone in Virginia from 1900 to 1908, inclusive.

Year	Granite Value	Sandstone Value	Slate Value	Limestone Value	Total Value
1900	$211,080	$ 6,000	$190,211	$403,318	$ 810,609
1901	275,701	5,303	178,979	986,177	1,416,160
1902	282,046	2,500	160,951	534,113	979,610
1903	299,335	4,471	115,356	569,205	988,367
1904	510,788	13,522	130,208	442,978	1,097,496
1905	452,390	2,000	146,786	212,660	813,836
1906	340,900	5,100	172,857	260,343	779,200
1907	398,426	(a)	173,670	362,062	935,158
1908	321,530	2,600	194,356	280,542	799,028

[a] Small value included with West Virginia.

The total value of the different kinds of stone quarried for the period of years for which statistics are given, shows that the quarrying of limestone is the largest industry in stone, with granite next, and slate third. For the past several years granite has been of first importance, although the difference in the annual value of its production and that of limestone is very small. The variation in limestone production is controlled in large part by the blast furnace conditions where it is used as a flux. The production of sandstone for the period represented in the table is relatively unimportant.

The value of the total production of stone in the State during 1908 was $799,028, as compared with $935,158 in 1907. This represents a loss of $136,130 or nearly 15 per cent. Of the total, granite quarries produced $321,530 or 40 per cent., limestone $280,542 or 35 per cent., slate $194,356 or 24 per cent., and sandstone $2,600 or less than 1 per cent. All kinds of stone showed a falling off in output in 1908 except slate. The stone industry in the State, however, will probably show an increase during the coming year because of the increased amount of building construction, road-building, and other purposes for which stone is used.

GRANITE

Granites, including the foliated type gneisses, have very wide distribution throughout the Virginia Piedmont region, constituting one of the dominant rock types. The general excellence of the Virginia granites as a building and ornamental stone has long been established in the commercial world. There is not a county within the limits of the Piedmont region that does not contain some granite, but the quarrying industry has thus far been limited to less than a half dozen counties.

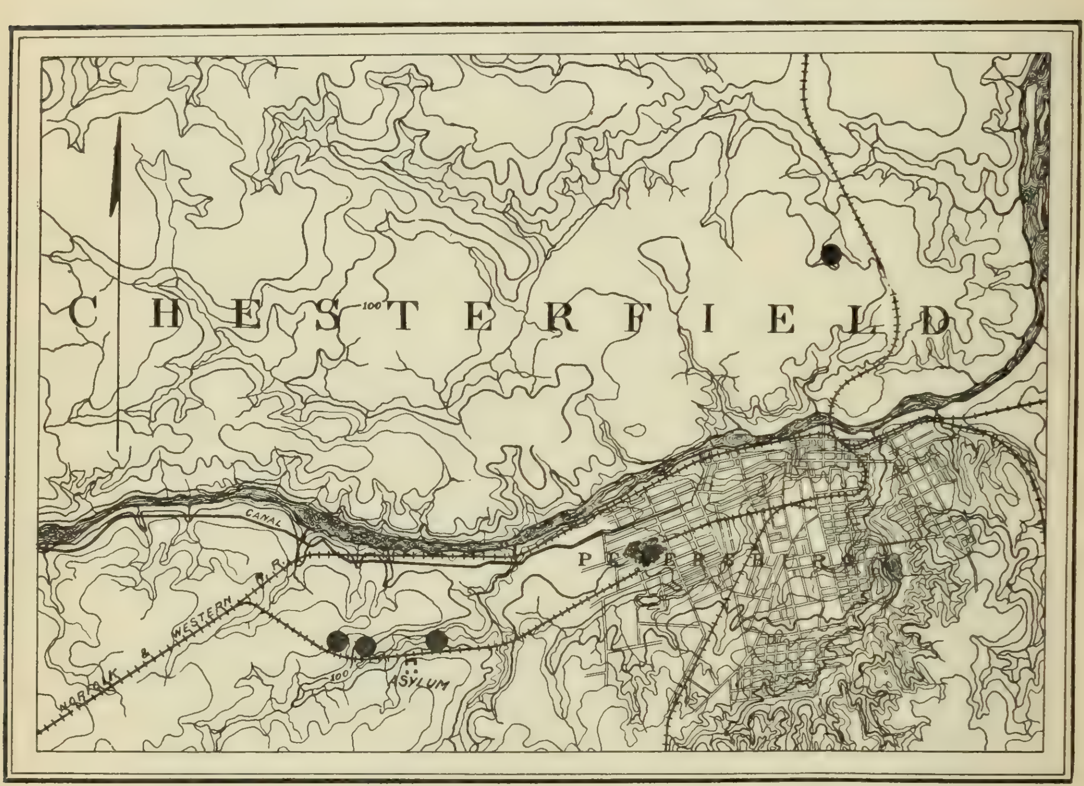

Fig. 13.—Map showing location of granite quarries in the Petersburg area. Quarries indicated by heavy dots. Based on U. S. Geol. Survey topographic sheets. Scale, $\frac{3}{8}$ inch = 1 mile, approximately. Contour interval, 20 feet.

The principal producing areas of massive granites are distributed along the eastern border of the Piedmont Plateau. They include (1) the Petersburg area, (2) the Richmond area, and (3) the Fredericksburg area. The principal counties composing these areas are Dinwiddie, Chesterfield, Henrico, and Spottsylvania. A small amount of granite has been quarried in a number of other counties within the limits of the Piedmont to supply strictly a local demand.

The granites of the State are chiefly granular aggregates of the minerals quartz, feldspar, and mica. Hornblende and epidote are important minerals in the granites of a few localities in the State, the latter being especially conspicuous in the variety of granite known as unakite, which is found in Madison, Page, and Grayson counties. Based then on mineral composition, we have the following varieties of Virginia granite: (1) Biotite granite, under which vastly the majority of the granites of the State belong; (2) muscovite granite; (3) hornblende-biotite granite; and (4) epidote granite.

The chemical composition of the granites in the Richmond, Petersburg, and Fredericksburg areas is shown in the table of analyses below. The specimens were collected by the writer and the analyses made in the Survey laboratory by Mr. Wm. M. Thornton, Jr., Chemist to the Virginia Geological Survey.

Analyses of Virginia Granites.

Constituents	I	II	III	IV	V	VI	VII	VIII
Silica (SiO_2)	72.27	71.51	71.19	70.83	69.48	69.44	69.29	68.45
Alumina (Al_2O_3)	14.30	13.82	14.01	12.70	13.95	15.46	14.07	10.00
Ferric oxide (Fe_2O_3)	1.16	1.76	1.66	2.67	2.82	1.31	2.59	5.71
Ferrous oxide (FeO)	0.97	1.20	1.29	1.36	1.70	1.43	2.03	2.59
Magnesia (MgO)	0.70	0.80	0.44	0.53	1.10	1.01	1.32	3.26
Lime (CaO)	1.56	1.79	2.04	1.88	2.81	2.11	2.76	6.20
Soda (Na_2O)	3.46	3.64	3.56	3.49	3.65	3.97	2.89	1.98
Potash (K_2O)	5.00	4.63	4.45	4.83	3.45	4.25	2.87	1.18
Water (H_2O) — 110°C.	0.04	0.17	0.04	0.07	0.04	0.07	0.06	0.18
Water (H_2O) + 110°C.	0.25	0.31	0.33	0.34	0.50	0.29	0.37	0.62
Titanium oxide (TiO_2)	0.31	0.33	0.35	0.41	0.47	0.48	0.50	0.20
Manganese oxide (MnO)	trace	0.03	0.02	0.03	0.03	0.03	0.08	0.05
Carbon dioxide (CO_2)	0.21	trace	trace	trace	trace	trace	trace	trace
Phosphoric acid (P_2O_5)	0.02	0.30	0.34	0.33	0.49	0.22	0.26	0.25
Total	100.25	100.29	99.72	99.47	100.49	100.07	99.09	100.67

I. Medium-textured and medium gray, biotite granite. Westham granite quarries, 4.5 miles west of Richmond, Chesterfield county.

II. Medium-textured and medium gray, biotite granite. Lassiter and Petersburg Granite Co.'s quarries, Petersburg, Dinwiddie county.

III. Fine-grained, dark blue-gray, biotite granite. McGowan, Netherwood, and Donald quarries, Chesterfield county, and Mitchell and Copeland quarry, Henrico county, near Richmond.

IV. Medium coarse-textured and medium gray, biotite granite. Netherwood, State (Old Dominion), Granite Development Co., Krimm and Middendorf quarries, Chesterfield county, near Richmond.

V. Fine-grained, dark blue-gray, biotite granite. Cartwright and Davis quarries, near Fredericksburg, Spottsylvania county.

VI. Medium-textured and medium gray, biotite granite. McIntosh quarry, Chesterfield county, 5 miles west of Richmond.

VII. Medium coarse-textured, gray, biotite granite-gneiss. Middendorf (Belt Line Railway) quarry, near Manchester, Chesterfield county.

VIII. Medium coarse-textured, gray, biotite granite-gneiss. Cartwright and Davis quarries, near Fredericksburg, Spottsylvania county.

The Richmond area is the principal granite producing area in the State. Not less than 20 quarries have been worked within the limits of the area, some of which are very extensive, being worked to a depth of

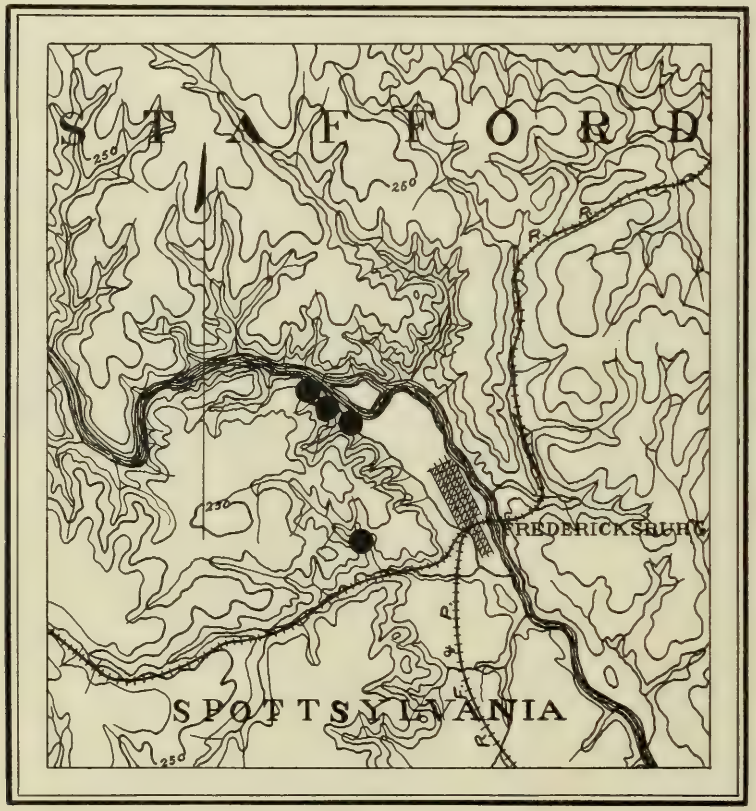

Fig. 15.—Map showing location of granite quarries in the Fredericksburg area. Quarries indicated by heavy dots. Based on the Fredericksburg topographic sheet. Scale, ⅜ inch = 1 mile, approximately. Contour interval, 50 feet.

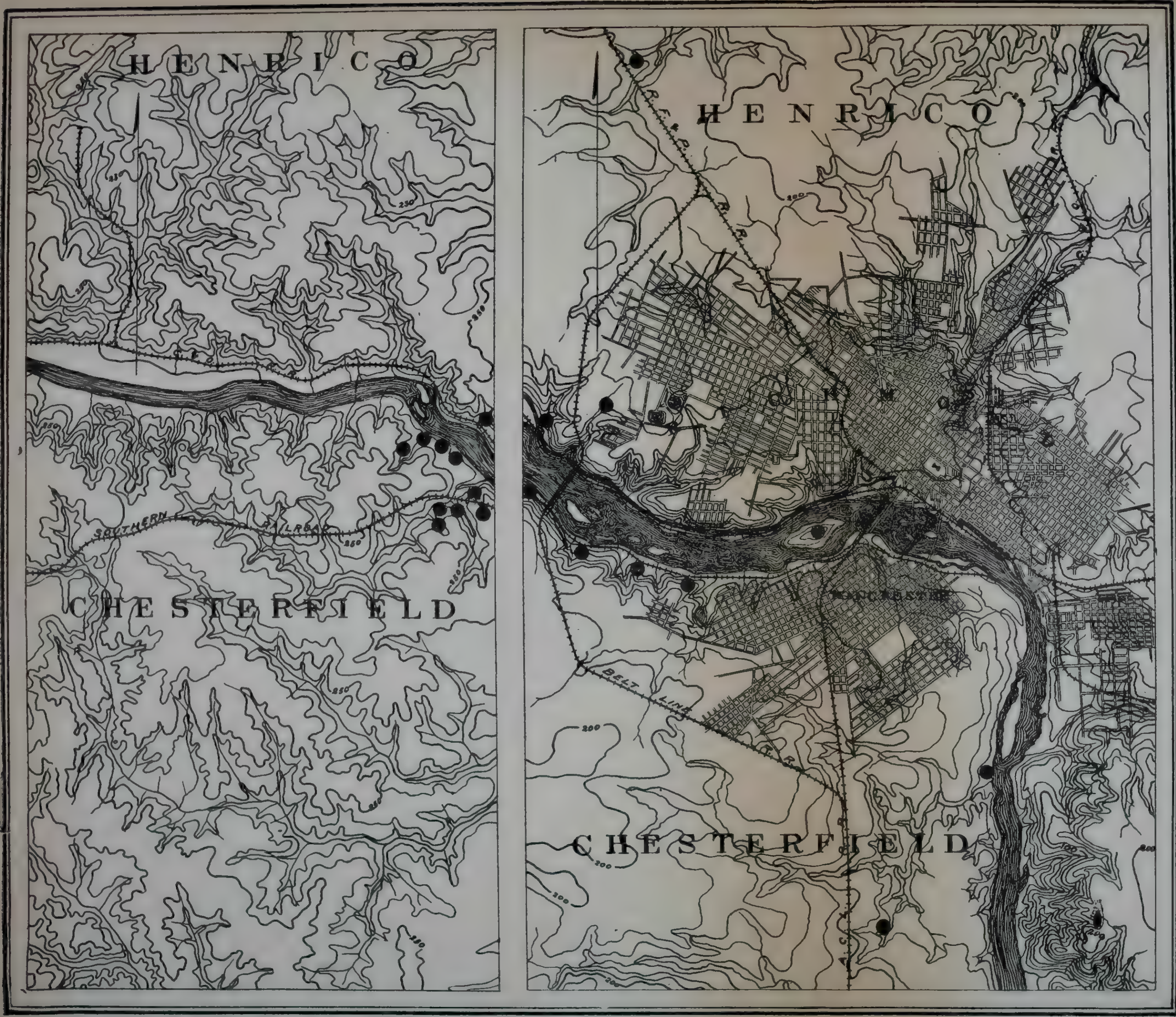

Fig. 14.—Map showing location of granite quarries in the Richmond area. Quarries indicated by heavy dots. Based on the Richmond and Goochland topographic sheets, U. S. Geol. Survey. Scale, Richmond sheet, 1 inch = 1 mile, approximately; Goochland sheet, ½ inch = 1 mile, approximately. Contour interval, Richmond sheet, 20 feet; Goochland sheet, 50 feet.

nearly 200 feet. Two grades of granite are quarried, one a fine-grained, dark blue-gray rock, extensively used as monument stock, the other a coarser grained and lighter colored gray rock admirably suited for building purposes. Both are homogeneous even-granular granites, possessing good working qualities. The fine-grained, dark blue-gray granite is susceptible of a high and permanent polish, and is a superior monumental stone.

Under the general head of granite are included such crystalline rocks as syenite, diorite, gabbro, and diabase, and the banded rocks known as gneiss and schist.

The production of granite last year was valued at $321,530, as against $398,426 in 1907, a loss in value of $66,896 or nearly 17 per cent. Nine counties contributed to this production as follows: Alexandria, Campbell, Chesterfield, Dinwiddie, Goochland, Greenville, Henrico, Prince Edward, and Spottsylvania. The uses made of the stone and the value of each are given in the table below.

There are given in the tables below the value and uses of the granite and gneiss quarried in Virginia during the years 1900-1908.

Value of Granite produced in Virginia, 1900-1908, by uses.

Use		1900	1901	1902
Sold in the rough...	Building	....	$ 40,763	$ 21,158
	Monumental	$ 12,000	8,300	12,500
	Other	....	230	....
Dressed for building..........		55,296	45,737	28,840
Dressed for monumental work......		21,461	52,404	51,612
Made into paving blocks..........		16,605	17,253	14,845
Curbing..........		8,810	7,977	29,796
Flagging..........		....		550
Rubble..........		....	43,029	26,255
Riprap..........		15,833		17,215
Crushed stone..	Road-making	38,850	9,850	6,133
	Railroad ballast		7,841	25,554
	Concrete		42,317	46,588
Other..........		....	....	1,000
Total..........		$211,080	$275,701	$282,046

Value of Granite produced in Virginia, 1900-1908, by uses.—Con.

1903	1904	1905	1906	1907	1908
$ 26,345	$ 33,613	$ 31,224	$ 18,158	$ 19,350	$ 26,769
13,440	17,320	10,415	15,804	8,039	12,664
....	....	....	200	....	1,075
14,740	48,452	28,950	....	13,275	4,000
43,845	55,608	37,180	16,936	9,787	29,803
28,034	30,966	19,220	29,536	18,072	10,173
4,582	33,324	8,948	14,339	6,000	6,130
5,485	3,516	2,550	1,216	....	....
28,449	40,524	28,961	28,477	16,350	18,270
22,410	7,630	27,236	31,790	28,852	16,336
31,785	12,940	21,175	34,981	59,937	21,670
17,400	61,352	69,360	64,386	50,804	92,895
60,820	165,043	166,364	85,077	167,960	81.745
2,000	500	807	....	....	....
$299,335	$510,788	$452,390	$340,900	$398,426	$321,530

Number and value of Granite Paving Blocks produced in Virginia, 1904-1908.

Year	Number	Value	Average Value per 1,000
1904............................	1,032,200	$30,966	$30.00
1905............................	913,440	19,220	21.05
1906............................	1,385,000	29,536	21.32
1907............................	685,100	18,072	26.38
1908............................	252,910	10,173	40.22

MARBLE

Marbles are found in the Mountain province west of the Blue Ridge and in the Piedmont province to the east, but there has been but slight attempt to develop them, owing chiefly to a lack of definite knowledge of their extent and quality. Bands occur in some of the limestones of the Mountain province, especially in the Shenandoah and Chickamauga formations, of a color and texture which adapt them to ornamental purposes. These show a variety of color and texture. White, gray, red, and black colors are found. These marbles have not received the attention which they apparently merit in places, and the developments thus far are slight.

Onyx marbles are fairly abundant in the limestone caves and caverns of the Valley region, but it is probable that these will rank as "uniques" rather than objects of commercial value. Large deposits of onyx marble are found near Bridgewater in Rockingham county, but they have not been investigated and very little is known of their quality.

Marbles of excellent quality occur in the vicinity of Goose Creek, Loudoun county. Samples of the white marble are not excelled for purity of color, fineness of grain, and general excellence, by that of any other marble in the United States. At Goose Creek, the marble bed is about 52 feet thick and has been worked to a considerable depth. The varieties shown are chiefly white, but there occur, also, banded blue and white, serpentinized white and green, pink and white, and green and white. These beds are pure, and the stone is of great beauty, and takes a good polish. The lack of transportation facilities, however, has thus far prevented extensive quarrying.

Undeveloped areas of marble are known in Grayson, Campbell, Nelson, and Pittsylvania counties. Openings were made in some of these many years ago and the stone burned into lime.

There has been no production of marble in Virginia for several years.

LIMESTONE

Limestone has its greatest distribution in the region west of the Blue Ridge where it forms one of the dominant rock types. It has had only a limited use for building purposes, but has been extensively quarried for use as a furnace flux, for lime-making in building and agriculture, for road metal and ballast, for concrete, and for the manufacture of Portland and natural cements. Four prominent sources of limestone obtain in this region, which, named in geologic order, are:

4. Greenbrier (Mississippian) limestone.
3. Lewistown (Helderbergian) limestone.
2. Ordovician (Trenton, etc.) limestones.
1. Cambrian limestone.

Of these four principal divisions of limestones, the Cambrian and Ordovician limestones constitute the Shenandoah (Valley) limestone group, which is the most persistent limestone group in the State. It is the underlying or basement rock of the Great Valley (Shenandoah) of

Virginia. The most important and only limestone which has been used in buildings is the Shenandoah limestone of the Great Valley. In its normal development, it is probably not less than 3,500 feet thick and in places it is much thicker. It has a wide range in composition and is divisible into several different members. The most important member of the Shenandoah limestone for building stone is the Natural Bridge limestone, which is usually a heavy-bedded, dark blue to gray magnesian limestone, frequently dolomitic. Quarries have been opened in it, in many places through the Valley region, and the stone used locally for building purposes.

The Lewistown and Greenbrier limestones have not been used for building purposes, but each has been quarried in places, especially the Lewistown, and used for fluxing the iron ores at the blast furnaces.

The value of limestone produced in 1908 was $280,542, as compared with $362,062 in 1907. This represents a loss of $81,520 in value or nearly 23 per cent. This decrease in production was due chiefly to a decrease in the amount of limestone used as flux in 1908, amounting to nearly 39 per cent. less in value than for 1907. There should be an increase in the production of limestone for this purpose during 1909, because of the fact that most of the iron furnaces which were closed down during a part or all of the year 1908, on account of the recent financial depression, will become active again. There were 30 producers of limestone operating in fourteen counties of the State. There is given below in tabular form the value of limestone produced in Virginia in 1908, by counties.

Value of Limestone Produced in Virginia in 1908, by counties.

County	Value
Alleghany	$ 62,465
Botetourt	51,380
Roanoke	43,713
Rockbridge	10,778
Shenandoah	2,539
Wythe	36,553
Other counties[a]	73,114
Total	$280,542

[a] Includes Augusta, Campbell, Giles, Loudoun, Pulaski, Rockingham, Washington, nd Wise.

The production of limestone in Virginia from 1902 to 1908, and the uses for which it was quarried are given in the table below:

Production of Limestone in Virginia from 1902 to 1908, by uses.

	1902	1903	1904	1905	1906	1907	1908
Rough building	$ 41,355	$ 5,325	$ 8,800	$ 5,390	$ 3,448	$ 3,170	$ 1,870
Dressed building			360	700	1,680	1,130	1,950
Paving						500	1,000
Curbing					275		79
Flagging							110
Rubble			168				
Riprap		22		120	323		
Crushed stone							
Road making		300	210	5,254	160	37,000	30,159
Railroad ballast	7,875	16,205	32,371	9,333	16,050	12,269	45,541
Concrete	11,580	9,238	5,668	11,187	18,700	32,326	26,604
Flux	220,001	199,989	117,882	180,676	219,707	275,517	169,847
Unspecified	11,318	1,665				150	3,382
Total	$534,113	$569,205	$442,978	$212,660	$260,343	$362,062	$280,542

SANDSTONE

Sandstones and quartzites occur in each of the three larger divisions of the State, but quarrying has been limited to only a few of the more accessible areas. There are large areas of these rocks not yet developed because chiefly of their remoteness from lines of railway and large centers.

The principal sandstone and quartzite formations in the State may be classified as follows:

COASTAL PLAIN.

1. Jura-Cretaceous sandstones along the "fall-line."

PIEDMONT PLATEAU.

2. Older quartzites in crystalline area of unknown age.
3. Newark (Triassic) sandstones.

APPALACHIAN MOUNTAINS.

4. Cambrian sandstones.
5. Silurian sandstones.
6. Devonian sandstones.
7. Carboniferous sandstones.

Excepting the areas of Triassic (Newark) sandstones, the quartzites and sandstones found east of the Blue Ridge, in the Crystalline area, are of unknown age. There occur an abundance and variety of this type of rock within the limits of the Piedmont. The rock has been quarried in many places, in years past, for use as a general constructional stone, and quarries are operated at present in a number of counties principally for crushed stone for road construction, ballast, and concreting. The stone ordinarily is firm, hard and compact, highly siliceous, very durable, and is admirably adapted to the uses made of it.

The Jura-Cretaceous and Triassic sandstones are practically the only ones which have been quarried and the stone shipped beyond the limits of the State. Of these, the Jura-Cretaceous sandstone, which occurs along the western margin of the Coastal Plain, was formerly extensively quarried in the vicinity of Acquia creek and on the Rappahannock river near Fredericksburg. The stone from these quarries was used chiefly in the construction of many of the older public buildings in Washington. These quarries were abandoned many years ago, largely, it is said, because of the unfitness of the stone for exposed work.

There are seven areas of Triassic rocks, composed in part of sandstone, distributed over the crystalline region east of the Blue Ridge. These comprise parts of twenty counties, and are designated as follows: (1) New York-Virginia area, (2) Richmond area, (3) Danville area, (4) Farmville area, (5) Scottsville area, (6) Barboursville area, and (7) Taylorsville area. The Triassic sandstone has been quarried in the vicinity of Manassas, Prince William county, and in the vicinity of Leesburg and Oatlands, Fauquier county. The Manassas quarries have yielded a stone that could be used with pleasing effects in a variety of combinations, and in quality not inferior to that in the more northern and eastern states.

The Cambrian sandstones are chiefly limited in distribution to the western base of the Blue Ridge and have been quarried locally, especially east of Basic, Augusta county, for railroad ballast. Sandstones of Silurian age have wide distribution west of the Blue Ridge, but they vary much in color, texture, and structure. Although possessing the essential properties in places requisite for a general constructional stone, the Silurian sandstones have not been quarried except for immediate local needs. The Oriskany sandstone of Devonian age is generally too friable to make a good building stone.

The Carboniferous comprises the greatest total thickness of sandstones of any single geologic system in the State. The rocks belonging to this system are limited in distribution to certain parts of the region west of the Blue Ridge, and are in part Mississippian and in part Pennsylvanian in age. The Carboniferous sandstones possess those qualities in some localities which make them desirable for building purposes, but as yet they have seldom been quarried, owing largely to a lack of demand for the stone and ample transportation facilities. They have been quarried in places in southwest Virginia for local use as a building stone and for heavy masonry.

The production of sandstone in the State is slight, and it varies greatly according to the local demands. The value of the annual production of sandstone from 1900 to 1908, inclusive, is shown in the accompanying table.

Value of Sandstone production in Virginia, 1900-1908.

Year	Value
1900	$ 6,000
1901	5,303
1902	2,500
1903	4,471
1904	13,522
1905	2,000
1906	5,100
1907	(a)
1908	2,600

[a] Small value included with West Virginia.

SLATE

Slate suitable for roofing and other purposes has been found in many localities within the limits of the State, and quarries have been

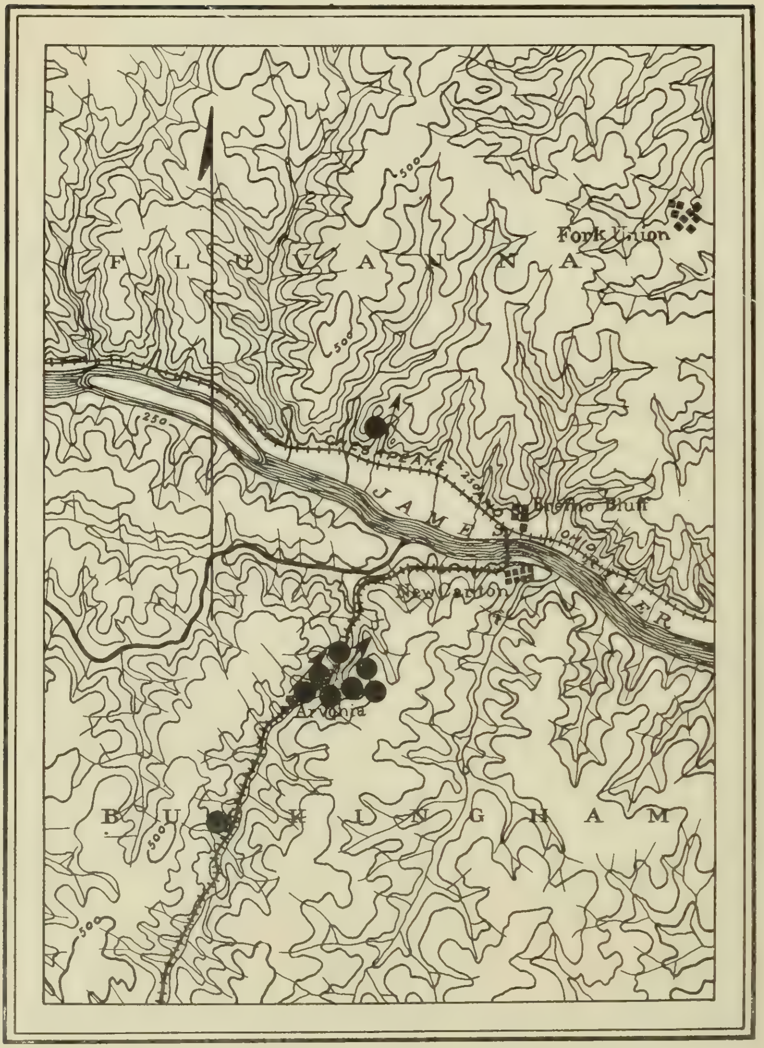

Fig. 16.—Map showing location of slate quarries in the Arvonia district, Buckingham county. Quarries shown by heavy dots; strike of commercial slate by arrows. Based on the Palmyra topographic sheet. Scale, ½ inch = 1 mile, approximately. Contour interval, 50 feet.

worked in Albemarle, Amherst, Buckingham, Fauquier, and Fluvanna counties. There are four principal slate areas and several minor belts in Virginia, which, named in the order of their present commercial importance are: The Buckingham-Fluvanna area, including outlying smaller belts to the west in Albemarle county; the Snowden area in Amherst county; the Fauquier-Culpeper counties' area; and the Quantico belt in Spottsylvania, Stafford, and Prince William counties. These areas are being studied and mapped by the State Geological Survey when, upon the completion of the chemical and microscopical studies, a volume will be published for distribution. Of the slate areas worked, that of the Arvonia district in Buckingham county, which forms a part of the Buckingham-Fluvanna counties' area, is the most important, commercially.

The slate produced in the Arvonia district is the most widely known in the South. There are ten operators in the district. The quarries are distributed along Hunts creek, for some distance north-northeast and south-southwest of Arvonia, a station on the Buckingham Branch of the Chesapeake and Ohio Railway, and is the shipping point. The quarries are very extensive, the largest averaging about 500 feet along the cleavage, 350 feet across, and 350 feet deep. The bedding and cleavage of the slate are identical, striking N. 33° to 37° E., and dipping 70° to 90° southeast, with a probable average of about 85°. The slate is very dark gray in color, with a faint greenish hue; is of minutely granular crystalline texture, and very lustrous surface. According to Dale, it is slightly graphitic and magnetitic, does not effervesce in cold dilute hydrochloric acid, and is very sonorous. Dale gives the constituents of the slate in order of their abundance as muscovite and sericite, quartz, biotite, carbonate, graphite (or carbonaceous matter), pyrite, chlorite, magnetite, with accessory plagioclase, zircon, hematite, tourmaline, and rutile.

Recent tests made by Professor Merriman on the slate from the Williams and Pitts quarries are given by Dale as follows:

Color and Firm.	Mark on Specimen.	Strength, modulus of rupture in pounds per square inch.	Toughness, ultimate deflection in inches on supports 22 inches apart.	Density, specific gravity.	Softness, amount in grams abraded by 50 turns of a small grindstone.	Porosity, per cent. of water absorbed in 24 hours.	Corrodibility, per cent. of weight lost in acid solution in 63 hours.
Blue.	W 1	8,590	0.17	2.788	0.073	0.105	0.281
	W 2	8,250	.19	2.754	.038	.090	.801
Williams Slate Company.	W 3	10,700	.31	2.795	.097	.209	.223
	W 4	8,620	.24	2.788	.033	.167	.270
	Means	9,040	.227	2.781	.060	.143	.394
Blue.	P 1	8,540	0.25	2.805	0.095	0.332	0.248
	P 2	9,010	0.18	2.790	.159	.....	0.552
A. L. Pitts Quarries.	P 3	11,970	.25	2.788	.138	.154	.275
	P 4	9,880	.22	2.781	.038	.163	.218
	Means	9,850	.225	2.791	.108	.216	.323

Although Dale's results on the microscopic study of the Arvonia slates show the presence of some carbonate, an appreciable amount of ferrous carbonate can not be present, for the use of these slates on buildings in Richmond more than 60 years ago, and on buildings near the quarries for more than a century, shows no discoloration whatever. Strength and durability would naturally follow from the highly crystalline character of this slate.

The Arvonia belt of slate extends for some distance northeastward across the James river into Fluvanna county, and has been opened at several places in the vicinity of Bremo, Fork Union, and Palmyra. Some recent prospecting of the slate in the vicinity of Fork Union and Palmyra, by the Old Dominion Slate and Cement Company, gave most encouraging results as to quantity and quality of the slate, and it is expected that systematic quarrying by this company will be begun at an early date.

About 20 miles west-northwest of the Arvonia belt is the Albemarle county slate belt. It has been prospected at several places, and quarries are operating in the vicinity of Esmont.

The Snowden slate belt occurs on the southeast side of the Blue Ridge, in the vicinity of Snowden station, in the southwest part of Amherst county. The belt has been prospected in a number of places, and the Williams Bros. Slate Company has successfully operated a quarry about three miles north-northwest of Snowden. The slate strikes N. 65° E., and has quartzite southeast of it which has been referred to the Cambrian. The cleavage strikes N. 45° E. and dips S. 60° E., and is cut by the original bedding planes which are quite strongly marked at an angle of 45° and more. The slate is very dark gray, has a minutely granular texture, moderately smooth cleavage, but with little lustre. It resembles the Arvonia slate in not effervescing with cold dilute hydrochloric acid and in being quite sonorous, but differs from it in not being graphitic nor magnetitic. Arranged in order of abundance, the chief constituents are, according to Dale, muscovite (sericite), quartz, chlorite, kaolin, pyrite, carbonate, rutile, and carbona-

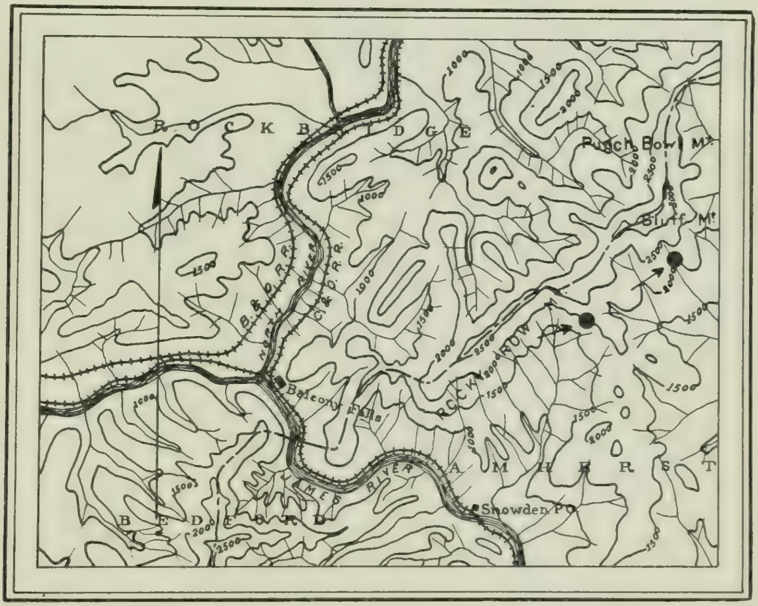

Fig. 17.—Map showing location of quarries in the Snowden district, Amherst county. Quarries shown by heavy dots; strike of commercial slate by arrows. Based on the Lexington topographical sheet. Scale, $\frac{3}{8}$ inch = 1 mile, approximately. Contour interval, 500 feet.

ceous matter. It is used exclusively for roofing and is a superior slate, though less crystalline than the Arvonia slate.

In Fauquier and Culpeper counties, slate outcrops are traceable to the north and south of the Rappahannock river in the vicinity of White Sulphur springs. The slate outcrops about one mile south of the springs, and is traced northward for a distance of two miles, with a minimum width of a half mile. The strike of the cleavage over most of the belt is N. 25° to 30° E., with a change in strike to an east-westward direction about three-quarters of a mile south of the springs. The slate is black, of moderately fine texture, and has but little lustre. It is very carbonaceous, shows much pyrite in places, contains no magnetite, does not effervesce with cold dilute hydrochloric acid, and has an argillaceous odor. In the northeasterly opening, Dale gives the

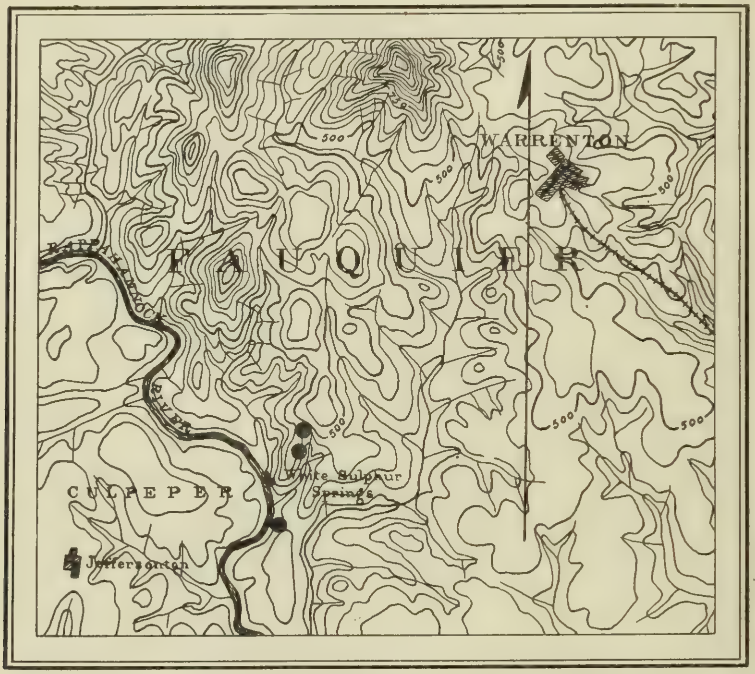

Fig. 18.—Map of the Fauquier county slate district. Quarries shown by heavy dots. Based on the Warrenton topographic sheet. Scale, $\frac{3}{8}$ inch = 1 mile, approximately. Contour interval, 50 feet.

chief constituents of the slate, arranged in the order of abundance, as carbonaceous matter, quartz, muscovite, feldspar, pyrite, and chlorite.

Investigations of this belt now in progress by the State Geological Survey indicate that pyrite is not present in harmful quantity in all parts of the belt, but that important commercial slate is found, and was quarried on a small scale from a number of openings many years ago, and used locally for roofing purposes.

In Prince William, Stafford, and Spottsylvania counties is one of the most extensive belts of slate in the State. This has been named the Quantico belt by Darton, from the creek by that name. In Stafford county, the slate is exposed in the "fall-line" gorge of Acquia creek, northeast of Garrisonville, and on Austin river, on the road a mile east of Garrisonville, and a mile and a half east, and half a mile south of Mountain View. It is exposed again in Prince William county to the northeast of Dumfries. No developments have been made on this belt, and it is not known whether it contains slate of commercial grade or not, but it is being carefully investigated by the State Geological Survey.

The total production of slate in Virginia during 1908 shows an increase in quantity and value. The figures of production were 41,678 squares, valued at $194,356, as against 39,172 squares, valued at $173-630 in 1907, a gain of 2,506 squares in quantity and $20,726 in value. In 1908, there were seven producers of slate operating in two counties, namely, Albemarle and Buckingham, with the principal part of the production from Buckingham county. The amount and value of the annual production from 1903 to 1908, inclusive, are given in the accompanying table:

Production of slate in Virginia, 1903-1908.

Year	Roofing Slate Number of Squares	Value	Average Price Per Square
1903	29,646	$115,356	$3.89
1904	31,852	130,208	4.08
1905	36,102	146,786	4.07
1906	39,068	172,857	4.42
1907	37,172	173,670	4.68
1908	41,678	194,356	4.66

The number of squares, as given in the above table, includes both first and second qualities, and the average price per square does not give a fair indication of the prices obtained for most of the stock.

CRUSHED STONE

The state-wide interest in good roads construction and improvement, and in the building of new lines of railway in Virginia during the past year, have greatly increased the demand for crushed stone. This material is used exclusively for road-making, railroad ballast, and concrete. In general with other industries, however, the production of crushed stone in the State received a setback in 1908, it being valued at $298,614, as compared with $360,296 in 1907, a decrease of $61,682 or 17.12 per cent.

Road Materials.—The road-building materials of Virginia are abundant and vary greatly in character. Nearly all varieties of stone used in highway construction are found in quantity in many sections of the State. The question of transportation is so important a factor that usually the best materials for road making can not be used in areas far removed from the sources of supply.

In Western Virginia—the Mountain province west of the Blue Ridge—limestones, sandstones, and shales are the principal rocks. Of these, limestone is the best suited for road making. It is found in quantity over most of the region, is easily worked, has good cementing or binding quality, but does not possess the durability of the igneous rocks when used as road metal.

In Middle Virginia—the Crystalline area or Piedmont Plateau—the rocks are largely highly crystalline metamorphic igneous and sedimentary types. These comprise granite, gneiss, schist, and the basic igneous types commonly known as trap, with local areas of slates, limestones, and quartzites. Of these, and in fact of all rocks, the basic igneous types, known as trap, make the best road metal. These rocks are tough and difficult to work, possess a high cementing value, great resistance to wear, and afford a valuable and permanent road metal. These rocks are widely distributed, occurring in practically every county in the Piedmont region.

In Eastern Virginia—the Tidewater or Coastal Plain province—

the rocks are of comparatively recent geologic age (late Mesozoic and Cenozoic), and consist chiefly of unconsolidated beds of sand, gravel, clay, and marl, which may be locally indurated by a cement either of iron oxide or carbonate of lime. The gravels and marls, when properly used, are of value in road construction, but they afford a less permanent road metal than the igneous rocks. The oxide of iron and carbonate of lime act as the cementing materials.

Ballast and Concrete.—With the exception of the marls, the materials used for railroad ballast and concrete are the same as those employed in road construction. The requirements are somewhat different from those of good road metal, since little or no binding power is required in railroad ballast, and cementing material is added in concrete.

The value of crushed stone produced in Virginia from 1903 to 1908 by years, is given in the table below.

Value of the Annual Production of Crushed Stone in Virginia, 1903-1908.

Year	Granite, Gneiss, Etc.			Limestone			Total
	Road	Ballast	Concrete	Road	Ballast	Concrete	
1903	$31,785	$17,400	$ 60,820	$ 300	$16,205	$ 9,238	$135,748
1904	12,940	61,352	165,043	210	32,371	5,668	277,584
1905	21,175	69,360	166,364	5,254	9,333	11,187	282,673
1906	34,981	64,386	85,077	160	16,050	18,700	219,354
1907	59,937	50,804	167,960	37,000	12,269	32,326	360,296
1908	21,670	92,895	81,745	30,159	45,541	26,604	298,614

FURNACE FLUX

Limestone, used in smelting operations for flux, is quarried and shipped to the numerous blast furnaces in the State. The utilization of limestone as flux constitutes the largest consumption of the Virginia stone. Each of the principal limestone horizons in western Virginia supplies some stone as flux to the iron furnaces, but the Cambro-Ordovician and Lewistown (Helderbergian) limestones are the principal sources of stone for this purpose. Of the total production of limestone in the State in 1908, 60.54 per cent. was sold as flux and utilized in the blast furnaces. Table on page 87 shows the total value of the limestone production in Virginia for all uses in 1908, to be valued at $280,542, of which $169,847 was the total value of limestone used as flux. Comparison of the figures for 1908 and 1907 shows a decrease in value of $105,670 for 1908 over that of 1907, of limestone used as flux, a decrease of 38.31 per cent. This decrease for 1908 over that of the preceding year was due to the fact that many of the iron furnaces were out of blast during 1908, owing to the recent financial depression, which naturally effected the iron industry. Conditions are expected to improve in 1909, and there should follow an increased production of limestone for use as flux.

There are given in the table below the annual production and value of limestone as furnace flux in Virginia from 1902 to 1908, inclusive.

Production of Furnace Flux in Virginia, 1902-1908, in long tons.

Year	Quantity	Value
1902	565,704	$220,001
1903	499,108	199,989
1904	273,826	117,882
1905	393,662	186,676
1906	467,341	219,707
1907	541,610	275,517
1908	290,487	169,847

ABRASIVE MATERIALS

Under this head are included corundum, emery, and millstones, but in 1908 the only abrasive material produced was millstones, which were quarried in Montgomery county.

CORUNDUM AND EMERY

The occurrence of corundum and emery has been noted in Virginia, but neither has been produced on a commercial scale.

Corundum.—The principal occurrence of corundum is in Patrick county, about two miles from Stuart, where it occurs on a knob of Bull mountain, in mica schists. It is grayish-white to white and colorless and, according to Pratt, is readily cleaned. Tests made for the cleaned product at this locality show that the corundum is well adapted to the manufacture of the vitrified wheel.

Emery.—Emery, a granular corundum of black or grayish-black color and containing magnetite or hematite intimately mixed, is found in considerable quantity a short distance west of Whittles in Pittsylvania county. Two openings about 300 feet apart and 20 feet deep have been made on apparently parallel "veins." Numerous smaller openings have been made near by. The rocks inclosing the emery are probably altered amphibolites or pyroxenites.

Miller describes the emery from the Pittsylvania county locality as a black crystalline mass, magnetic, polar, with a specific gravity of 4.205 and a hardness of 8. An analysis of the emery gave Miller the following results:

	Per cent.
Alumina	56.74
Ferric oxide	15.50
Ferrous oxide	20.77
Silica	0.68
Titanic oxide	1.86
Soda	3.95

MILLSTONES (Buhrstones)

Under this name is included a siliceous conglomerate of quite variable structure, used in the form of flat-circular disks for grinding purposes.

About five miles west of Blacksburg, in the vicinity of Prices Fork, Montgomery county, a sandstone-conglomerate occurs in Brush mountain, in which quarries have been opened for a distance of three miles. The rock is somewhat variable in color, but is usually of some light shade, white or gray. Likewise variation in the size of pebble is shown. The rock is made up of well-rounded pebbles of quartz compactly imbedded in a fine siliceous sandstone matrix, the whole forming an exceedingly tough and hard mass. This rock is known on the market as "Brush Mountain" stone. Practically the same variation in the sizes of stone made at the different quarries obtains. The sizes of stone produced in 1908 as reported to the State Survey office were, 14, 15, 16, 20, 24, 26, 30, 36, 42, 48, and 54 inches.

The grindstones made from this rock are of excellent quality and find a ready market. The geologic age of the "Brush Mountain" stone is Mississippian (Lower Carboniferous) or Vespertine of Rogers.

Similar siliceous conglomerates occur in other counties of the State, especially in some of the counties of the Mountain province, but the Brush mountain quarries, in Montgomery county, are the only producing ones.

The production of millstones in Virginia during 1908 was valued at $7,954, as against $4,684 in 1907, an increase in value of $3,270 or 41.1 per cent. The value of millstones produced in Virginia for the years 1902-1908, inclusive, follows below in tabular form.

Value of Millstones Produced in Virginia, 1902-1908.

Year	Value
1902	$11,435
1903	9,812
1904	4,759
1905	8,186
1906	15,611
1907	4,684
1908	7,954

SILICA

Under this heading are included three forms of silica which have rather wide distribution in the State. These are quartz, chert, and diatomaceous earth.

QUARTZ

Quartz has wide distribution in the State. It occurs as an essential constituent in granite, gneiss, and mica schist of the crystalline area; as the dominant constituent in the sandstones, quartzites, and conglomerates of the Piedmont and Valley regions; and in the form of sand over parts of each of the larger geologic divisions of the State. A principal occurrence of quartz in Virginia, that is of commercial value, is in the form of pegmatite dikes and quartz veins penetrating the older metamorphic rocks of the Piedmont region.

There was no reported production of quartz in 1908. It has been mined, however, in association with mica and feldspar, from the large pegmatite dikes near Amelia Courthouse, in Amelia county, and from a bedded deposit in crystalline schists near Falls Church, Fairfax county, where the quartz forms a hard and beautifully white, fine-granular, quartzite.

CHERT

Chert, known also as hornstone, a term applied to any impure flinty rock, including the jaspers, is a chalcedonic variety of silica. Chert has wide distribution in certain beds of the Shenandoah or Valley limestone of the Valley region, in the form of irregular nodular masses of light nearly white, red, brown, and black colors. No special use has yet been made of the Virginia chert.

DIATOMACEOUS EARTH

Diatomaceous earth, known in the trade under the name of "silica," "infusorial earth," or "tripoli," is composed of the minute shells or tests of microscopic plants known as diatoms. It was first reported from the vicinity of Richmond, Virginia, and for that reason received the name of "Richmond earth," under which term it is sometimes referred to in the literature. Because of its occurrence at Bermuda Hundred, on the James river, it has also been called "Bermuda earth."

The first bed of diatomaceous earth of any extent discovered in this country was in the Richmond area. It is known as the Richmond bed, which extends from Herring Bay on the Chesapeake, Maryland, to Petersburg, Virginia, and probably beyond. It is not less than 30 feet in thickness in places, though very impure at times. It is of Miocene age, and is exposed along the numerous streams close to their crossings from the crystalline rocks on to the sediments of the Coastal Plain.

The diatomaceous earth has been dug from time to time in the vicinity of Richmond for commercial use. There has been no reported production of this material in Virginia for several years.

MICA

Commercial mica, which includes the varieties known as muscovite and phlogopite, usually occurs in pegmatite dikes penetrating granites, gneisses, and schists. The pegmatites usually consist of a coarse crystallization of quartz and feldspar in varying proportions, with or without mica, and other accessory minerals. They vary in thickness from a few inches to several hundred feet, are often irregular in outline, and may be parallel to or break across the schistosity of the inclosing rocks. In small veins the mica is frequently too small in size to have commercial value. Both the quartz and the feldspar of the pegmatites are of value, and are sometimes mined with the mica and utilized in the manufacture of pottery and for abrasives.

Pegmatites containing commercial mica are somewhat abundantly developed in many of the Virginia Piedmont counties, and many excellent surface indications for mica occur, but as yet prospecting and mining have been confined to only a few of them. Mica has been either prospected or mined in the following counties in Virginia: Near Amelia and Jetersville, Amelia county; near New London and at Lowrys, Bedford county; Goochland county; near Chatham, Pittsylvania county; near Axton and at Ridgeway, Henry county; near Hewlitts, Hanover county; near Farmville and at Prospect, Prince Edward county; Amherst, and Charlotte. Indications of mica occur also in Buckingham, Caroline, Cumberland, Franklin, Powhatan, and Spottsylvania counties.

The Jefferson mine near Amelia, opened in 1873, was the first mine worked for mica in Amelia county, and was soon followed by the opening of other mines in the vicinity. These were the Berry, Pinchback, Rutherford, and Winston, near Amelia, and the Schlegal, near Jetersville. The Pinchback and Schlegal mines are the only regularly worked mica mines in Amelia county during recent years.

The mica of the Amelia district occurs in pegmatites cutting a thinly foliated, biotite gneiss, which, in places, shows a distinct "augen" texture. The proportion of mica, quartz, and feldspar in the pegmatites is quite variable. The feldspar varieties include orthoclase, microcline, and albite. A considerable number of accessory rare minerals have been found in the Amelia pegmatites. These are microlite, fluorite, columbite, helvite, monazite, allanite, garnet (spessarite), apatite, beryl, zircon, and tourmaline. Some of these have been used for gems.

The Pinchback mine has been worked by more than a half dozen openings, the last one of which, made in 1906, shows the pegmatite to be 40 feet thick. The feldspar is kaolinized along the walls to a depth

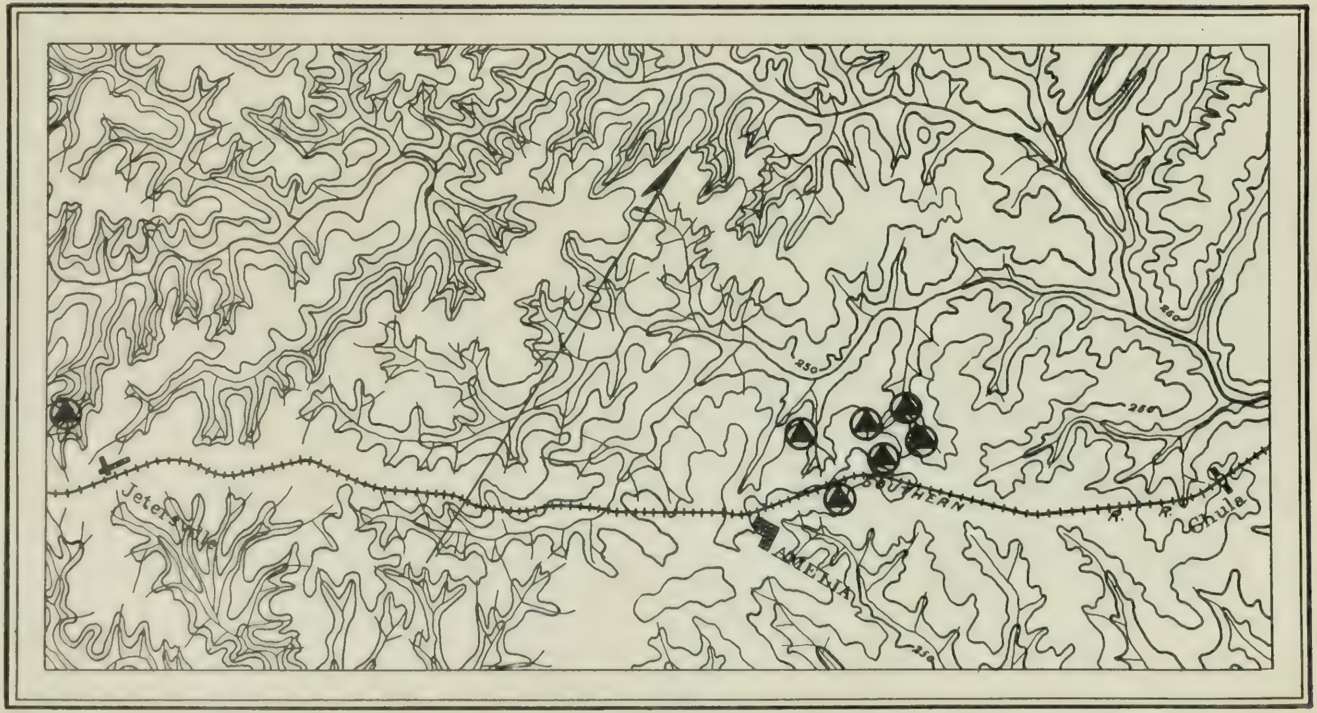

Fig. 19. Map showing location of mica-feldspar mines in Amelia county. Mines indicated by heavy triangles in circles. Based on topographic sheet, U. S. Geol. Survey. Scale, ½ inch = 1 mile. Contour interval, 50 feet.

of 28 feet, and it was shipped to pottery works when the mine was in operation. Mining of mica has again been resumed at the Schlegal mine after an idleness of six or seven years. It was worked by an open cut and shaft 100 feet deep with several drifts, and, besides mica, furnished feldspar for pottery works. The feldspar was ground in a mill at the mine before shipping. The pegmatite, in which the mine is opened, is about 30 feet thick as measured on the surface at the open work, and cuts irregularly across the strike of the country gneiss.

The mines owned by the Hanover Mica Company, near Hewlitt, in Hanover county, were the first mines worked for mica in Virginia. These were first worked from 1867 to 1870 by Barr, Johnson and Company, of Erie, Pennsylvania, with a production of more than 60,000 pounds of clipped stove mica, which at the time resulted in overstocking the then limited market for such material. The mines were then closed down and remained idle until 1883, when they changed hands. Work was resumed for only a brief period because of the death of the owner, and remained idle until purchased in 1907, by Mr. A. Ford, of Washington, D. C. In the fall of 1907, machinery was installed at the lower opening, which was pumped of water and cleared of debris, and some exploratory work done with very encouraging results. Machinery was also installed at the upper opening, a tram track laid, and all was in readiness when the recent financial panic came, and work was temporarily abandoned. About 1,000 pounds of rough mica of excellent grade and clear white color were worked from the mines during the fall of 1907. Some of this was reported to be about 18 by 33 inches in size. Mining is expected to be resumed as soon as the spring of 1909 opens.

The Pittsburg Mica Company's mine at Ridgeway, Henry county, was developed by an open cut about 100 feet long and 40 feet deep, and much cross-cut work. The plant completed at the mine in 1907 was destroyed by fire in 1908, which greatly curtailed the production of mica by the company for the year.

The production of mica in Virginia during 1908 was smaller than for some of the preceding years. The figures were 13,427 pounds of sheet mica and 46 tons of scrap, with a total valuation of $7,346. It came from Jetersville, in Amelia county; and Burnt Chimneys and Ridgeway, in Henry county. At each of these localities mining continued through only a part of the year. The production by the Pittsburgh Mica Company at Ridgeway, Henry county, was greatly curtailed because of the destruction of the plant by fire. No production was reported from Amelia, in Amelia county, nor from Hanover or Bedford counties, although development work was in progress in each of these counties during 1908, and mining will be resumed in 1909.

There should be an increased production of mica in Virginia during 1909, as preparations were in progress during 1908 for the resumption of mining in 1909 at a number of mines which had been idle for some time, and several new properties were being opened with reported encouraging results.

The table below gives the quantity and value of sheet and scrap mica produced in Virginia in 1908.

Production of Mica in Virginia for the year 1908.

Sheet Mica		Scrap Mica		Total Value
Quantity Pounds	Value	Quantity (Short tons)	Value	
13,427	$5,941	46	$1,405	$7,346

FELDSPAR

The feldspar group includes a number of mineral species which chemically are silicates of aluminum with varying amounts of lime, and the alkalies, potash and soda. Of the nine known species of feldspar only a few are of commercial value, the principal ones being the potash varieties, orthoclase and microcline, and the soda variety, albite. Orthoclase or microcline, or an intergrowth of these two, are the species most commonly used by potters in this country. The potash feldspars are frequently associated with small quantities of the soda feldspar, albite, which occurs either as separate crystals or intergrown with the orthoclase or microcline.

Commercial feldspar usually occurs associated with quartz and mica as coarse crystallizations in pegmatite dikes, cutting granites, gneisses, and crystalline schists. Pegmatites are rocks usually of extreme coarseness and of irregular texture and composition. Dikes of pegmatite containing feldspar as an important constituent are quite widely distributed throughout the Virginia Piedmont region, hardly a county within the region being without them. Notwithstanding the abundance of these dikes in the Virginia Piedmont province, many of which contain commercial feldspar, the attempts to mine the mineral are comparatively few, and as yet the production is small and variable. Feldspar has been mined in Amelia, Bedford, Hanover, Henry, and Prince Edward counties. In a majority of these counties feldspar has been mined with the associated mica of the pegmatites.

The following analyses indicate the character of the feldspar mined in Amelia, Bedford, and Prince Edward counties:

Analyses of Feldspar in Virginia Pegmatites.

	I	II	III	IV	V
Silica (SiO_2)	65.37	64.12	67.06	63.25	65.75
Alumina (Al_2O_3)	18.74	16.84	21.72	20.33	20.04
Iron oxide (Fe_2O_3)	0.13	2.28	....	....	0.27
Lime (CaO)	0.27	0.32	1.59	....	trace
Magnesia (MgO)	....	0.26	0.03	....	trace
Potash (K_2O)	12.98	13.34	0.38	12.85	12.45
Soda (Na_2O)	2.49	1.88	10.01	1.35	1.18
Water (H_2O)	....	....	....	....	0.42
Total	99.98	99.04	100.79	98.78	100.11
Specific gravity	2.501	2.564	2.618	....	2.593

I. Orthoclase from Amelia county. E. B. Sloan, analyst.
II. Microcline from Amelia county. C. C. Page, analyst.
III. Albite from Amelia county. Robert Robertson, analyst.
IV. Orthoclase from Bedford county. Golding Sons Company, analysts.
V. Potash feldspar from Prince Edward county. F. A. Genth, analyst.

Potash feldspar was produced at three quarries in Virginia during 1907, namely, near Bells, in Bedford county, near Prospect, in Prince Edward county, and near Amelia, in Amelia county. The product from these quarries was shipped crude to the pottery works at Trenton, New Jersey. There was only one producer of feldspar in Virginia during 1908, namely, near Prospect, in Prince Edward county and the production is included under "other products" in the table on page 5. The product was shipped crude to East Liverpool, Ohio, for grinding and use in the manufacture of pottery ware. Some development work was in progress at the quarry near Hewlitt, in Hanover county, during 1908, and it is expected that this quarry will again become a producer in 1909.

ASBESTOS

Prior to 1907, Virginia was a producer of asbestos for a number of years. No production was reported in 1907 or in 1908. The mineral has been noted in a number of the Piedmont counties, and it has been mined in Amelia, Bedford, and Franklin, principally the two latter. The mines have been inactive since 1906 and the mill at Bedford City for fiberizing the asbestos is closed.

In Bedford county, the mines of the American Asbestos Company are located near Chestnutford post-office, about 12 miles south of Bedford City, on the Hubbard farms. According to Diller,[a] the asbestos rock is of two types. The first type is like that of Sall mountain, Georgia, and is composed essentially of fibrous amphibole, the fibers of which are arranged in groups or bundles lying in all directions, and is derived from pyroxenite. The other type is a peridotite composed chiefly of granular olivine, with numerous acicular crystals and fibrous bundles of anthophyllite. Diller[b] states that this type is cut by a few small veins of cross-fiber anthophyllite, one-eighth to three-quarters of an inch in length. The fiber is flexible, somewhat elastic, has numerous cross fractures, and is relatively short and brittle. The asbestos mined occurs as vein-like masses of slip fiber, lying parallel to the plane of slipping, which cut the rock as occasional planes of shearing. These masses are very irregular, locally 18 inches thick, and along the strike have a length of about 30 feet.

In Franklin county, a small amount of asbestos was recently mined from a 40-foot shaft a short distance east of Rocky Mount. The asbestos-bearing rock[c] is amphibolite, which locally contains some olivine, and is much altered to chlorite and serpentine. The asbestos is found in a vein which lies parallel to the schistosity of the inclosing amphibolite.

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[a] Diller, J. S. Mineral Resources of the United States, Part II, Nonmetallic Products, 1907, p. 718.

[b] Ibid. pp. 718–719.

[c] Ibid. p. 719.

with strike S. 50° E. and steep dip to the northeast. The principal constituent is probably tremolite.

TALC AND SOAPSTONE

Virginia is by far the most important state in the United States in the production of soapstone, which has wide distribution over the Piedmont region. It has been noted in the following counties: Albemarle, Amelia, Amherst, Bedford, Buckingham, Campbell, Carroll, Charlotte, Fairfax, Floyd, Fluvanna, Franklin, Grayson, Henry, Louisa, Nelson, Patrick, and Stafford. Many of the deposits are of excellent grade, and the stone has been quarried on a commercial scale in at least six of the above-named counties; but practically the entire production in Virginia at present comes from the Nelson-Albemarle counties belt.

In Fluvanna and Buckingham counties, soapstone was quarried many years ago on a small scale near the mouth of Hardware creek, and the product used locally for hearths, jambs, and other parts about chimneys. It is also made use of further east in the southern part of Fluvanna county, at Bremo, and an excellent grade of it occurs at several localities in the vicinity of Palmyra.

In Albemarle county, a little west of Green mountain, is a belt of soapstone associated with quartzites and micaceous schists, which is traced southwestward through Nelson into Campbell, Bedford, and Franklin counties. The belt widens in Nelson county and is associated with some serpentine. It passes thence as a narrow belt along the western base of Buffalo Ridge, in Amherst county, crossing the James river above Lynchburg, and is exposed about two miles west of the city on the road leading to Bedford City, and is exposed again two and a half miles west of New London, in Bedford county. Continuing in the same direction, the stone is seen again at the meadows of Goose creek, where it has been quarried to some extent. Continuing still further westward, it is exposed in several nearly parallel belts, of which the most eastern makes its appearance near Pig river in Franklin county. A second belt occurs in the same vicinity near the eastern base of Jack's mountain; a third still further west about one mile from Rocky Mount; and a fourth yet more to the west on the eastern slope of Grassy Hill. The stone has been quarried in a small way at several places in Franklin county, near Rocky Mount, and used strictly for local purposes. Extensive quarrying operations are in force in the Albemarle-Nelson counties' portion of the belt, which is described in some detail below.

In Amelia county, south of Chula, and about four miles from Amelia, soapstone of good quality was quarried quite extensively many years ago. A second more extensive area of soapstone of excellent quality occurs on the north side of Flat creek, about four and a half miles north of Jetersville. On the headwaters of Walnut creek, a tributary to Flat creek, soapstone has been quarried to some extent. Quarrying was begun in 1904, and during the summer of 1906 numerous other smaller openings were made nearby. This property is controlled by the Tip Top Soapstone Company, and much preliminary work was in progress during 1908 preparatory to systematic quarrying in 1909.

In Louisa county, soapstone of good quality is reported to have been quarried near Oakland and Trevilians.

In Fairfax county, soapstone occurs two miles east of Annandale, one mile east of Tenley, and east of Falls Church. In each of these localities, the soapstone occurs as lenticular bodies closely associated with basic eruptive rocks, and were probably derived from peridotite and pyroxenite. All of these bodies have been worked to some extent, and in the Annandale area much stone has been quarried and sawed. The stone is of good quality, even-grained, and of uniform light bluish-green color, without seams and schistose planes developed in it. Small quarries of soapstone are operated in Fairfax county, near Clifton and Wiehle. At the former, soapstone is ground, but at Wiehle it is sold in the crude state just as it is taken from the quarry.

In Henry county, near Spencer's store, quarries of soapstone were opened some years ago. The material was of excellent quality, and blocks of any required dimensions were reported to have been quarried. These were sawn out and then finished by planing. They were used in the foundations of houses and for other purposes.

In Albemarle and Nelson counties, the soapstone belt is a short distance west of Green mountain, and, to the east, near and approximately parallel to, Hawkins, Finley, Ball, and Appleberry mountains. It has a general northeast-southwest direction, and is three to five miles southeast of the main line of the Southern Railway, which it roughly parallels. Quarries have been opened on the belt at numerous points for a distance of nearly 30 miles. In many places, the belt is apparently separated into several (three) parallel members locally called "veins." It has a probable extreme width of from 500 to 800 feet, and dips usually to the southeast, in conformity with the inclosing micaceous schists and quartzites which strongly suggests conformable stratification, but the occurrence of the soapstone is in dike-like masses and in more intimate association with a rock of igneous origin from which it was derived. Several of the most extensively worked quarries have reached depths of more than 120 feet. The larger quarries are well equipped with all necessary modern machinery for getting out the stone, including channeling machines for quarrying the rock, and at each quarry is a mill for sawing, dressing, rubbing, and polishing the stone, and other machines for grooving and drilling holes. The excellent quality of this stone adapts it to a wide range of uses, the principal ones including laundry tubs, sanitary purposes, electrical purposes, sinks, and cooking utensils.

In Stafford county, soapstone of reported good quality occurs near Garrisonville, and preparations were being made during 1908 by the Austin Run Mining Company to begin quarrying in 1909.

The production of talc and soapstone in Virginia during 1908 suffered a considerable reduction over that of 1907. The figures were 19,616 short tons, valued at $458,252, as compared with 26,278 short tons, valued at $631,880 in 1907, a decrease in quantity of 6,662 tons, and in value $173,628 or 27.4 per cent. The 1908 production was obtained from nine producers, operating in three counties, which named in the order of importance of their production were Nelson, Albemarle, and Fairfax. Only a small proportion of the total quantity of talc and soapstone quarried in Virginia is sold in the crude state. The talc and soapstone production is classified in the following four groups: Rough or crude, sawed into slabs, manufactured articles, and ground.

In the following table are given the quantity and value of soapstone produced in Virginia during 1908, according to the condition in which it was marketed.

Production of Talc and Soapstone in Virginia during 1908, according to varieties.

	Quantity (Short tons)	Value
Rough	1,030	$ 2,832
Sawed into slabs	3,346	70,748
Manufactured articles[a]	15,040	383,672
Ground[b]	200	1,000
Total	19,616	$458,252

[a] Includes washtubs, laboratory or kitchen sinks, stove bricks, griddles or other mill stock.

[b] For paint, paper filling, complexion powders, lubricants, etc.

There is given in the table below the yearly production of talc and soapstone in Virginia from 1905 to 1908, inclusive:

Production of Talc and Soapstone in Virginia, 1905-1908, in short tons.

Year	Quantity	Value
1905	17,665	$425,090
1906	23,624	590,800
1907	26,278	631,880
1908	19,616	458,252

BARYTES

Barytes has been mined for many years in various parts of the State. The earliest mining of this mineral in Virginia was probably in 1845, in Prince William county, within 600 feet of the Fauquier county line, about four miles south of east from Catlett. Mining operations in Campbell and Pittsylvania counties, in the Piedmont region, and near Marion, in Smyth county, in the Valley region, were begun about 33 years ago. The mining and milling of barytes on a commercial scale in Tazewell and Russell counties are more recent, and commenced about 18 years ago.

Barytes occurs in many counties in the State, but the industry has been confined to only a few of them. The counties in which it is found are: (1) those east of the Blue Ridge in the crystalline area, and include Amherst, Bedford, Buckingham, Campbell, Fauquier, Louisa, Nelson, Orange, and Prince William; and (2) those counties west of the Blue Ridge, and comprise Bland, Botetourt, Frederick, Montgomery, Rockbridge, Russell, Smyth, Scott, Tazewell, Warren, Washington, and Wythe. Of these, Bedford, Campbell, Pittsylvania, and Prince William counties, of the Piedmont province, and Russell, Smyth, and Tazewell counties, of the Mountain province, have practically yielded the entire production of the State.

Geologically, the barytes deposits found in the Piedmont region are associated either with the crystalline metamorphic rocks (limestone, chiefly) of unknown age, or with the Triassic red shale-sandstone series, and those of the Mountain region are usually associated with the Shenandoah limestone of Cambro-Ordovician age or its residual decay.

In the Triassic area of Prince William county, barytes has been mined about four miles south of east from Catlett. It is associated with red shale and impure limestone, usually filling fractures of from four to eight feet wide in the red shale, and in thin, tabular, cleavable masses in the limestone. During 1908, deposits of barytes of good quality and in quantity are reported to have been opened in the vicinity of Bealton, Fauquier county, and preparations were being made to mine the ore in 1909.

In the crystalline area, the principal production of barytes has been from Campbell, Bedford, Louisa, and Pittsylvania counties. The Campbell-Pittsylvania counties' area is traced for a distance of about 50 miles southwestward, beginning in the middle western portion of Campbell county, several miles east of Evington, and about 15 miles south of Lynchburg to three or more miles south of Sandy Level, in the northwestern part of Pittsylvania county. The most extensively worked deposits in this area are grouped about two centers, Evington, in Campbell county, at the northeast, and Toshes and Sandy Level, in Pittsylvania county, at the southwest extremity of the area. The principal mines in the Campbell portion of the area are the Hewitt, Saunders, Phillips, and Anthony, grouped near together and within a few miles east and southeast of Evington. Of these, the Hewitt mine has been the most extensively worked. It was worked almost continuously from 1874 until 1904, when it was abandoned on account of water. It is

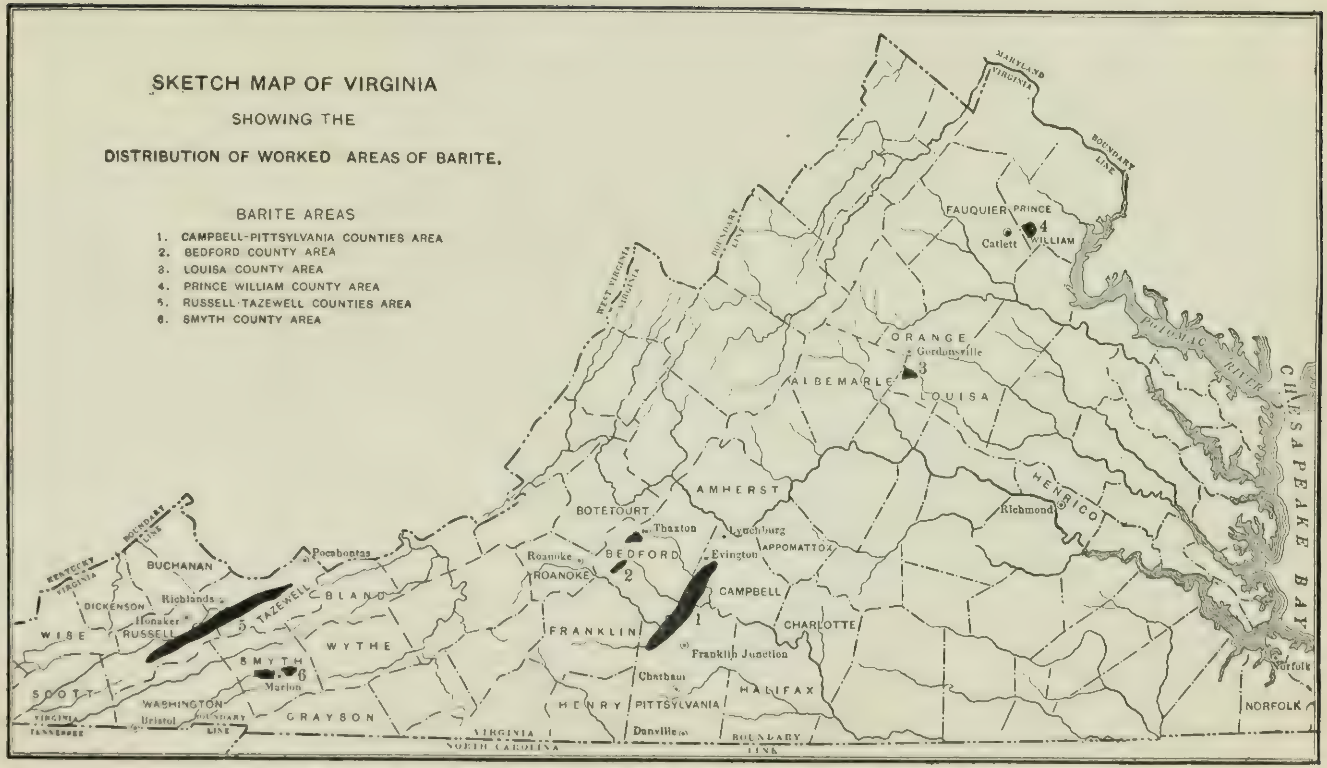

Fig. 20.—Sketch map of Virginia showing distribution of worked areas of barytes.

developed by numerous shafts and drifts, the greatest depth reached in mining being about 160 feet.

The barytes in the extreme northwest corner of Pittsylvania county has been more extensively worked than in any other part of the belt. It has been developed by a large number of mines, grouped in two nearly parallel belts on either side of Pig river, just south of its entrance into Roanoke river. The following mines have been opened in this part of the belt: Berger, Bennett, Davis, Hatchet, Meas, Parker, Thompson, and Wright.

Numerous openings have been made at different points on the belt between the two centers mentioned above, many of which have been extensively worked and have produced large quantities of excellent ore. The barytes occurs in the Campbell-Pittsylvania counties' belt in intimate association with the crystalline limestone as irregular lenticular bodies or pockets, which measure from 100 to 200 feet or more, replacing the limestone. For the depths thus far attained in mining, there is immediately above and below the limestone, a variable thickness of a nearly black clayey mass, usually preserving the foliation of the original rock from which it was derived, and colored black from manganese oxide. Through this black clayey mass are usually distributed, in irregular fashion, lumps and nodules of barytes of large and small sizes.

Near Thaxton, in Bedford county, barytes occurs in a schistose, coarse-grained granite, filling a fracture. About three miles south of east from Lindsay, in Louisa county, barytes has been mined from a number of test pits and several shafts, the deepest one of which is between 70 and 80 feet. The barytes occurs in pockets having a thickness of about three feet where worked, and probably represents a filling of an irregular fracture in the crystalline schists.

In southwest Virginia, the barytes is found in association with the Shenandoah limestone or its residual decay. It fills in part, at least, fractures in the limestone, and in part it replaces the limestone. In the clay derived from the weathering of the limestone, the barytes is found in nodules of large and small size irregularly distributed through the clay.

Mining of barytes in Virginia is surface work, with no deep mining in any part of the State. The greatest depth yet reached in any of the mines is 160 feet in a shaft recently operated at the Hewitt mine, in Campbell county. In the crystalline area, east of the Blue Ridge, the ore is won by vertical timbered shafts and drifts which follow the direction of the ore bodies. In the limestone belt of southwest Virginia, the mining is shallow and largely by open pit work.

In the preparation of the ore, the removal of impurities from the better grades includes washing, bleaching, and grinding, and occasionally jigging as the only necessary operations. The common impurities in the best grades of ore include iron oxide and manganese oxide, limestone, clay, and sand. The ore in the limestone of southwest Virginia is both jigged and washed before bleaching and grinding.

The barytes mined in Virginia is prepared for market at the following mills in the State: the plant at Lynchburg, owned by Nulson, Klein and Krausse; the plant at Honaker, owned by the Clinch Valley Barytes Company; the plant at Richlands, owned by the Pittsburgh Barytes and Milling Corporation; and the plant at Bristol, owned by John T. Williams and Sons. These mills are modern, of large capacity, and fully equipped with machinery.

There was a decided falling off in the mining of barytes in Virginia during the year 1908. The entire production was from the Campbell-Pittsylvania counties' area, and was valued at $17,572, as against $32,833 in 1907, a decrease in value of 46.4 per cent. The average price per ton was considerably higher in 1908 than in 1907, the figures being $4.55 and $3.55, respectively, for the two years.

The following table gives the quantity, total value, and average price per ton of the barytes produced in Virginia from 1902 to 1908, inclusive:

Production of Crude Barytes in Virginia, 1902-1908, in short tons.

Year	Quantity	Value	Average price per ton
1902............	12 400	$39,700	$3.20
1903............	5,700	20,400	3.58
1904............	11,214	31,452	2.84
1905............	6,468	27,838	4.30
1906............	11,775	45,336	3.85
1907............	9,254	32,833	3.55
1908............	3,866	17,572	4.55

GYPSUM

Commercial deposits of gypsum in Virginia occur associated with salt in Washington and Smyth counties, in the valley of the North Fork of the Holston river. The rocks are associated with rocks of Mississippian (Lower Carboniferous) age. They are limited to the narrow belt on the northwest side of the Saltville fault, included between the fault and the Carboniferous shales and sandstones of the basal slopes of Pine and Little Brushy mountains. So far as has been made out, this narrow belt is composed of the Greenbrier limestone (Lower Carboniferous), and the beds of salt and gypsum. The position of the fault and of the mines is shown on the accompanying map on page 117.

Gypsum of excellent quality has been mined at numerous points in the Valley between Plasterco and within three miles west of Chatham Hill. The exact date of the discovery and first working of the gypsum is unknown to the writer, but it certainly dates back as far as the early part of the nineteenth century. The mines of the Buena Vista Plaster and Mining Company at Plasterco, Washington county, and of the Southern Gypsum Company, three and a half miles northeast of Saltville, Smyth county, are the most extensive in the valley and were the only ones that produced in 1908. The production for 1908 is included under "other products" in table on page 5.

A number of borings were made on the property of the Buena Vista Plaster and Mining Company between the years 1815 and 1857 for the purpose of ascertaining (1) the thickness of the gypsum, and (2) the presence of brine or rock salt. The records of seven of these borings, taken from Bulletin No. 213 of the United States Geological Survey, are given below:

Well A. Bored between 1815 and 1820:	Feet
Red clay	0– 14
Clay and plaster	14–120
Pure plaster	160–200

Well B. Bored in 1847:	
Red clay	0– 10
Clay and plaster, buhrstone	10– 30
Clay and plaster (deep red)	30– 50
Pure plaster	50– 95
Impure blue plaster	95–163
Hard blue slate	163–420

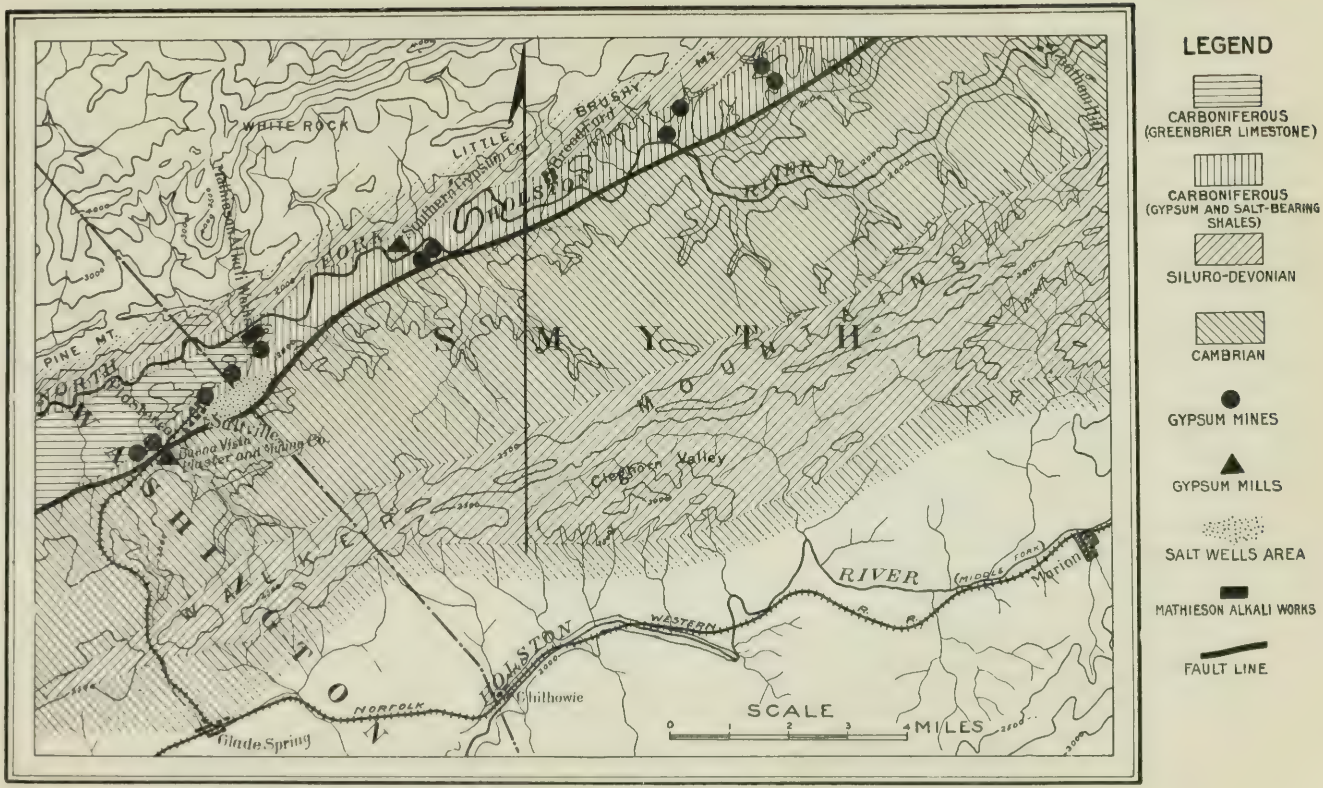

Fig. 21.—Map of the salt and gypsum deposits of southwest Virginia. Based on topographic sheet, U. S. Geol. Survey. Geology partly adopted from Stevenson.

	Feet
Well C. Bored in 1847:	
Red clay	0– 10
Clay and plaster, with brown rocks	10– 70
Pure plaster	70–100
Slate and plaster	100–200
Hard blue plaster	200–360
Red slate	360–480
Gray slate	480–495
Red rocks, a little salty	495–505
Well D. Bored in 1847:	
Red clay	0– 10
Clay and plaster	10– 62
Plaster, with a little clay	62–200
Red clay, with a little plaster	200–385
Red clay, alkali, and salt	385–387
Pure plaster	387–590
Well E. Bored in 1847:	
Red clay	0– 10
Clay and plaster	10– 16
Impure plaster	16– 50
Pure plaster	50–102
Slate and plaster	102–165
Nearly all plaster	165–210
Blue slate	210–320
Blue slate and plaster	320–390
Yellow soapstone	390–445
Pure plaster	445–490
Red rock, with a little salt	490–505
Well F. Bored in 1853:	
Clay	0– 17
Clay and plaster	17– 50
Pure plaster	50– 83
Hard black flint rock	83– 90
Pure plaster	90– 96
Plaster and sulphur balls	96–105
(Record lost)	105–109
Red and yellow soapstone	109–120
Hard blue slate and red, blue, and gray rock	120–359
Yellow and blue slate	359–390
Yellow and blue slate, salty	390–460
Well G. Bored in 1854:	
Sand and gravel	0– 20
Blue clay	20– 30
Hard white sand rock	30– 40
Clay and plaster	40– 55
Buhrstone	55– 60

An underground examination of the gypsum, in the openings of this company, indicates the occurrence of gypsum with much admixed anhydrite in huge boulder masses, in gray and red clays. Both clays are abundant, the red being softer than the gray and is utilized to some extent in the manufacture of plaster. The gypsum as mined is ground and calcined at the milling plant located at the mines, and the product is used chiefly as calcined and wall plasters, and as land plaster.

The Southern Gypsum Company began prospecting on its property, three and a half miles northeast of Saltville, in the summer of 1906. After nearly a year of drilling, the company demonstrated a large supply of gypsum and erected a mill with the capacity of 400 tons per day. The product of this company is put upon the market chiefly in the form of wall plaster and land plaster.

SALT

Salt brines and rock salt occur in the Holston Valley of southwest Virginia in association with gypsum. The salt and gypsum deposits are confined to a narrow northeast-southwest valley of the North Fork of the Holston river, extending from Plasterco to within three miles of Chatham Hill, a distance of about 16 miles. The interbedded salt and gypsum shales with beds of rock salt and gypsum are regarded as of Mississippian (Lower Carboniferous) age.

In 1771, Jefferson mentioned in his "Notes on Virginia," the occurrence of salt brine in the Holston Valley, but it was not until 1840 that rock salt was discovered. A shaft was sunk in 1840 which struck a bed of rock salt at a depth of 210 feet. A large number of wells have been bored, ranging in depth from 300 to 1,400 feet, the greatest depth reached being 2,380 feet. There are 24 producing wells at present. The first borings for salt in this valley were in the old swampy lake-covered area near the present site of the town of Saltville. Mining of the rock salt has not been attempted, the entire salt product being derived from the salt brines of the wells. The entire salt industry at present is confined to the immediate vicinity of Saltville, and is controlled by the Mathieson Alkali Works.

In the early history of operations and, indeed, until within recent years, the product marketed was salt, which for many years amounted to between a half million and a million bushels of salt per year. The Mathieson Alkali Works stopped the making of salt in 1903, and from that time until 1908 the brines were utilized exclusively for the manufacture of sodium carbonate and caustic soda. The product was of superior merit from the start, and because of this fact, a large and growing trade has been acquired. The manufacture of salt was again resumed in 1908 by the company, but, since there was only one operator, the figures of value of the production are combined with those of another subject, in order not to disclose private business.

MINERAL PAINTS

Ocher of more or less purity is found, and has been mined to some extent in each of the principal geologic divisions of the State, namely, the Coastal Plain, the Piedmont Plateau, and the Valley region. It has been mined at the following localities in Virginia: In the extreme eastern part of Chesterfield county, near Bermuda Hundred, on the Appomattox river; in the Little Catoctin mountain, near Leesburg, in Loudoun county; near Bedford City, in Bedford county; near Keezletown, in Rockingham county; from the western base of the Southwest Massanutten mountain, near Stanleyton, in Page county; and near Shenandoah Station, in Page and Rockingham counties.

In addition to these, ocher deposits are found rather widely distributed over the Valley and Piedmont provinces, and to some extent over the Coastal Plain, which have not been worked. In the Valley and Piedmont provinces, the ocher deposits are frequently associated with beds of iron ore. Deposits of ocher varying in color from red, yellow, and brown, and which seem particularly promising but not yet developed, are found in Campbell and Bedford counties; near Bon Air, in Chesterfield county; near Fairfield, in Rockbridge county; near Waynesboro, in Augusta county; and near Roaring Run, in Craig county.

The production of ocher and mineral paint in Virginia in 1908 amounted to 1,235 short tons, valued at $10,705. Preparations were being made for the opening of deposits near Garrisonville, in Stafford county, and Snowville in Pulaski and Montgomery counties.

MARL

Calcareous and greensand marls are widely distributed over the Coastal Plain or Tidewater region of Virginia. Calcareous marls are also found in places in the Valley region west of the Blue Ridge. They have not been developed in Virginia, however, except for local use.

The greensand marl is Eocene in age, and is formed chiefly along the inner margin or western portion of the Coastal Plain, where it is exposed along the Potomac, Rappahannock, Pamunkey, and James rivers. It also occurs on the interstream areas, and has been traced southward from the James river almost to the State line. The greensand marls contain a small percentage of potash and frequently phosphoric acid, the potash content varying according to the quantity of the mineral glauconite present. Shells are usually present in the deposits and supply lime in addition to potash and phosphoric acid. These marls have value as a fertilizer, and have been worked at a number of places on the James and Pamunkey rivers.

The calcereous (shell) marls are abundant over much of the Coastal Plain region, being especially so in the Miocene and, in places, hardly less abundant in the Eocene. The deposits are quite extensive in some localities, and contain as much as 80 to 97 per cent. of calcium carbonate in places. In addition to their agricultural value, many of the beds are large enough and of sufficient quality to be used in the manufacture of Portland cement. The State Geological Survey is investigating these deposits with a view to their use in Portland cement manufacture, and it is confidently believed that several plants will be built in the near future in Tidewater Virginia for the manufacture of Portland cement from these marls. It is hardly necessary to call attention to the advantages afforded in this region in water transportation.

There was no production of marls in Virginia during the year 1908.

PYRITE AND PYRRHOTITE

The tabulation of production and value of pyrite in Virginia by years, given on page 126, includes both pyrite and pyrrhotite. Virginia has long held the position of first producer of pyrite among the pyrite-producing states in the United States.

Commercial pyrite occurs in Louisa, Stafford, Spottsylvania, and Prince William counties. Mines are opened in each of these counties, but the production has been from Louisa and Prince William counties. The pyrite mines in these two counties are probably the largest and most extensively developed ones in the United States, and the product from them constitutes nearly 50 per cent. of the total output of pyrite in the United States.

The pyrite mines in Louisa county were worked at different times for iron, copper, and pyrite. They were first opened and worked for iron in 1834, when the gossan overlying the pyrite for a depth of from 40 to 60 feet was mined for iron-making in the local furnaces. The Prince William county mine, near Dumfries, was first opened in 1889, but was not continuously operated until several years later.

The pyrite deposits in Louisa and Prince William counties occur as lenticular bodies, usually of large size, lying conformable or nearly so with the structure (foliation) of the inclosing rock. The lenses follow each other in the direction of strike, and may or may not be connected by thin and lean stringers of ore. The spacing between the ends of lenses is variable. In a few instances, partial overlap of the lenses has been observed. The lenses vary much in size, those in the Louisa county mines measuring several hundred feet long and as much as 60 to 80 feet in thickness.

As developed by the extensive mining operations, the ore-bodies are marked, in places, by rolls and swells and by pinching and narrowing. The inclosing rocks are metamorphic crystalline schists, chiefly micaceous, with more or less of the minerals, hornblende and garnet, developed in places. The normal rock is a mica-quartz schist, but mica schist without quartz, largely altered to chlorite, quartz-sericite schist, talcose and chloritic schists, and hornblendic schist, occur. Bands and stringers of more or less pure limestone are found in the walls near the ore bodies. Associated with these, is a considerable development of lime-bearing silicate minerals.

The ore consists of the massive-granular type, which varies in texture from very fine- to moderately coarse-grained. Some of it is very hard and non-friable, but much of it is quite friable, and in some mines practically all the ore is of the latter type. Much of the ore is admixed

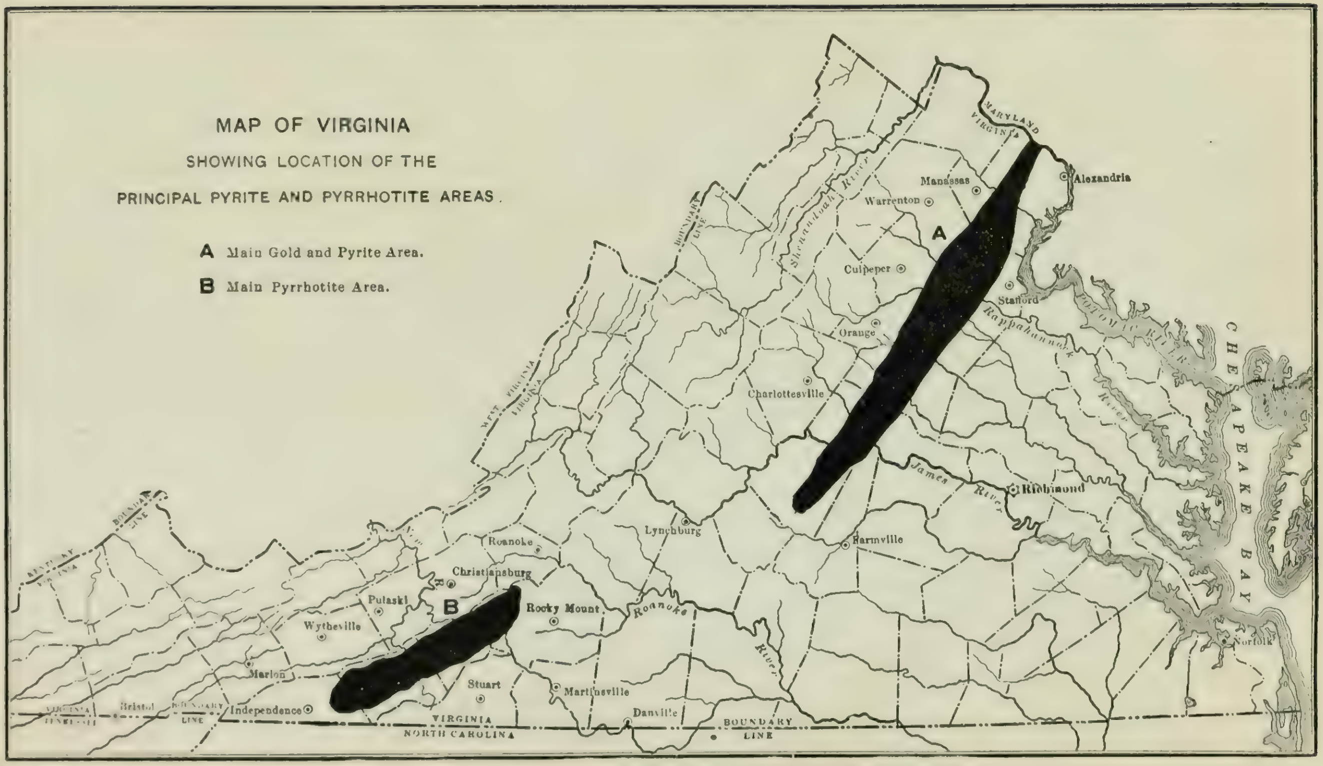

Fig. 22.—Sketch map of Virginia showing pyrite and pyrrhotite belts.

with white granular calcite and some quartz. Chalcopyrite, sphalerite, galenite, pyrrhotite, and magnetite are associated with the pyrite in small quantity. Chalcopyrite is present in sufficient quantity at some

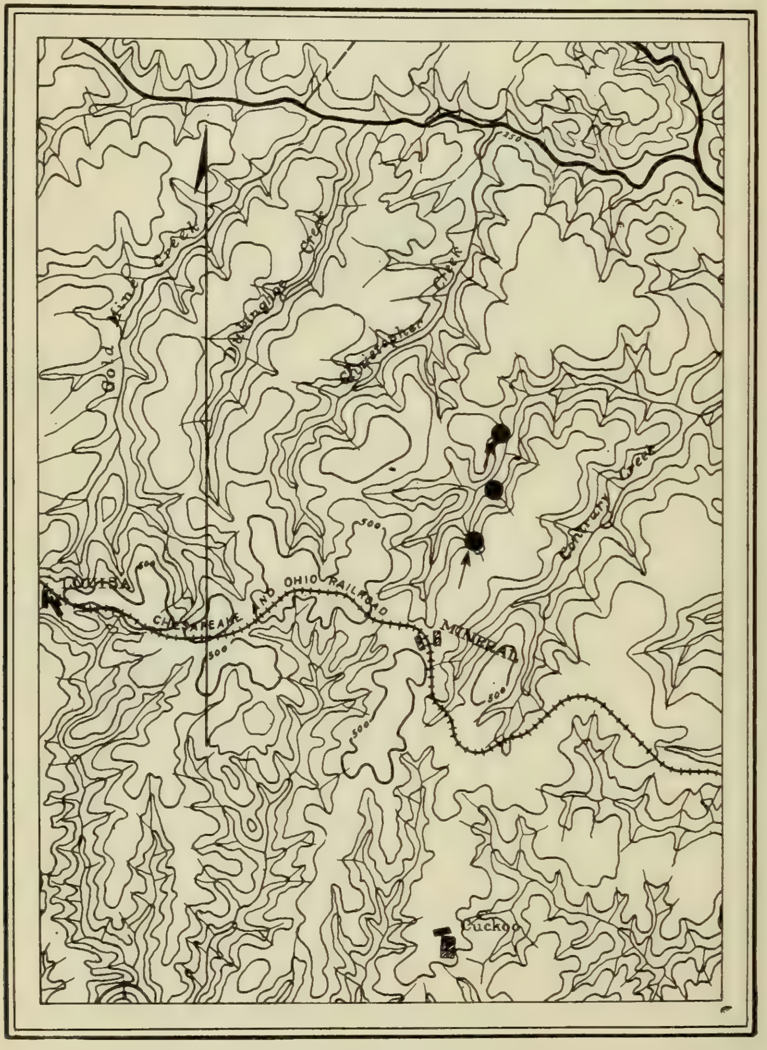

Fig. 23.—Map showing location of pyrite mines in Louisa county. Mines shown by heavy dots; strike of schistosity by arrows. Based on topographic sheets, U. S. Geol. Survey. Scale, ⅝ inch = 1 mile, approximately. Contour interval, 50 feet.

mines to warrant the saving of the copper from time to time by precipitation of it from the mine water, when it is dried, screened, and barreled for market. Sufficient chalcopyrite is encountered in the Cabin Branch pyrite mine near Dumfries, in Prince William county, to warrant the building recently of a small smelter for the extraction of the copper.

The principal occurrence of pyrrhotite in Virginia is that of the "Great Gossan Lead" in Floyd, Carroll, and Grayson counties (map, figure 25). This "lead" forms a well-defined vein of pyrrhotite varying in width up to 100 feet, and strikes southwestward from Floyd county, through Carroll into Grayson county, a distance of more than 20 miles. It is composed chiefly of pyrrhotite with admixed quartz and schist, and carries streaks and patches of chalcopyrite and pyrite. The vein fills a fault fracture in crystalline schists of unknown age, varies in width from a few feet to 100 feet, shows a somewhat variable but average dip of about 45°, and has in general an approximate northeast trend.

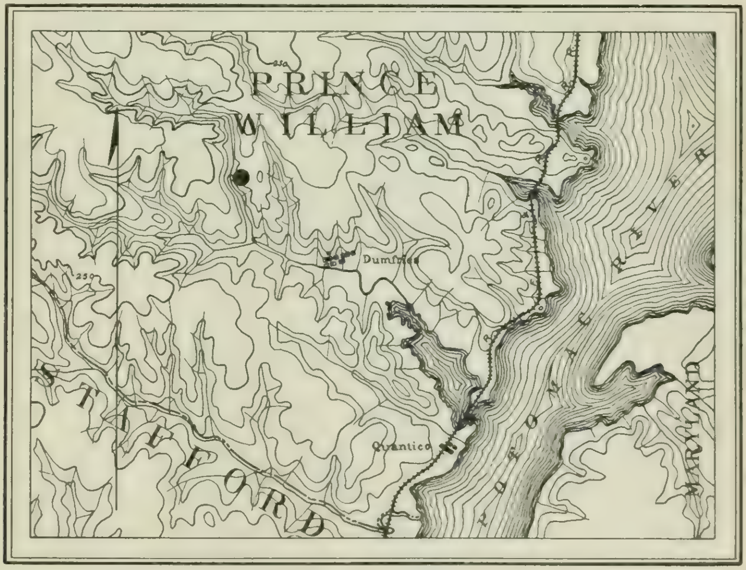

Fig. 24.—Map showing location of Cabin Branch pyrite mine, Prince William county. Based on the Mt. Vernon topographic sheet. Scale, ⅝ inch = 1 mile, approximately. Contour interval, 50 feet.

The region was actively prospected in the early fifties for rich secondary copper ores found beneath the gossan, and during 1854-5 there were eight producing mines on the "Gossan Lead." At present, pyrrhotite is mined by the Pulaski Mining Company near Monarat, Carroll county, and the ore treated at Pulaski for sulphur.

The total production of pyrite, including pyrrhotite, in Virginia during 1908, shows a decrease in quantity of 8,400 long tons, with a gain in value of $62,936 over 1907. The increase in value is due to a higher average price per ton of the ore in 1908 than in 1907, the average price per ton being $3.74 in 1908, and $2.99 in 1907. The figures of production in 1908 were 116,340 long tons, valued at $435-522, as compared with 124,740 long tons, valued at $372,586 in 1907. The production in 1908 was from three different localities, namely, Mineral, Louisa county; Dumfries, Prince William county; and Monarat, Carroll county.

During 1908, two new mines were developed in Stafford and Spottsylvania counties, which are expected to be added to the list of producers of pyrite in 1909. These were the Austin Run Mining Company, near Garrisonville, Stafford county, and the Spottsylvania Sulphur Mines, near Spottsylvania, Spottsylvania county.

There is given in the table below the production of pyrite in Virginia from 1904 to 1908, inclusive.

Production of Pyrite in Virginia, 1904-1908, in long tons.

Year	Quantity	Value	Average price per ton
1904	120,671	$440,753	$3.65
1905	123,183	426,008	3.46
1906	128,794	431,388	3.35
1907	124,740	372,586	2.99
1908	116,340	435,522	3.74

ARSENIC

Virginia has not been a producer of arsenic for several years. In 1903, the United States Arsenic Mines Company, of Pittsburg, Pennsylvania, began the mining of arsenopyrite (mispickel) at Rewald, in Floyd county. An extensive plant, erected for refining the product, was started in 1904, with the monthly capacity increased after January,

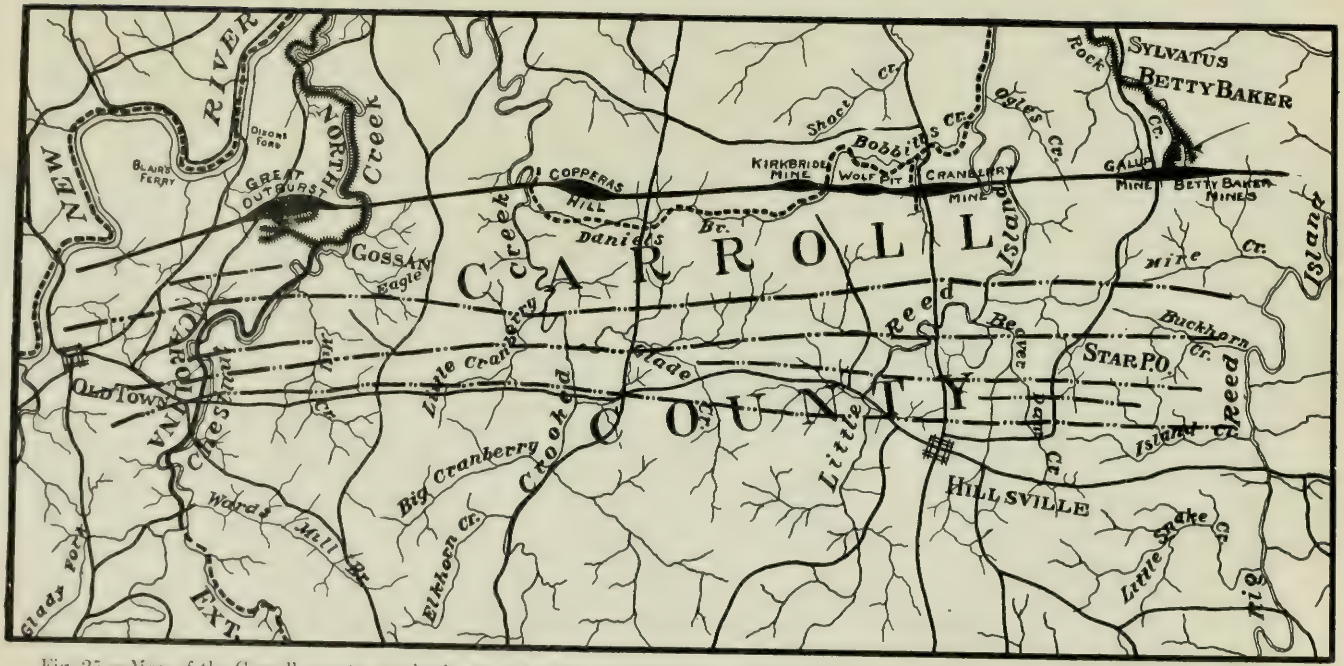

Fig. 25.—Map of the Carroll county pyrrhotite area, showing position of the "Great Gossan Lead' in heavy black band and the principal copper mines located on it. Broken lines indicate other probable leads.

1905, to 90 tons of pure white arsenic. Operations were temporarily abandoned several years ago, but it is reported that mining will be resumed in 1909.

The mines are located 17 miles from Christiansburg, at Rewald, Floyd county. The ore is arsenopyrite, a double sulphide of arsenic and iron, and occurs in "veins" (lenses) in quartz-sericite schist, which is closely associated with biotite gneiss, but the relations of the two rock types to each other, and of the gneiss to the ore bodies, are unknown. The principal ore body (lens) is reported to be three feet thick at the surface but widens to a thickness of fourteen feet at a depth of 120 feet.

PHOSPHATE

Three forms of phosphatic material occur in the State; namely, (1) the marls of the Coastal Plain region, (2) pebble phosphate west of the Blue Ridge near Clifton Forge, and (3) dikes of nelsonite—a rock composed normally of a mixture of the minerals ilmenite and apatite occurring in Nelson county.

The shell and greensand marls of the Coastal Plain region frequently carry a small but variable percentage of phosphoric acid. These marls are not rich enough, however, in phosphoric acid to render them of commercial value as a source of phosphate.

West of the Blue Ridge, the occurrence of phosphatic nodules has been observed at the base of Devonian black shale, at Clifton Forge, but the extent of this material is yet unknown.

The nelsonite dikes in Nelson county are numerous and extend over a considerable area. Much variation is shown in the mineral composition of the rock composing the dikes. Normally, the rock is a granular mixture of the minerals white apatite and black ilmenite in variable proportion. Either mineral may predominate over the other in quantity. Near Rose's Mill, the ilmenite of some of the dikes is largely or entirely replaced by rutile giving a rock composed essentially of apatite and rutile with little or no ilmenite. In the vicinity of Lovingston, some of the dikes are composed principally of magnetite and biotite with a variable amount of apatite, while others are made up almost entirely of apatite. Chemical analyses of the nelsonite, collected from dikes over different parts of the area, show the calcium phosphate to range as high as 33 per cent.

The occurrence of the rock nelsonite in this county has been known for many years, and it has been prospected in a small way by open pits, cuts, and shafts at a number of places, chiefly near Roseland, Bryant, Rose's Mill, and Lovingston. The development work in the nelsonite dikes, near Rose's Mill, by the General Electric Company, is for the mineral rutile and not for the phosphate mineral apatite.

The dikes of nelsonite in Nelson county represent the largest concentration of phosphatic material yet known in the State. These deposits are being studied and mapped in detail by the Virginia Geological Survey, and a bulletin setting forth the results at considerable length will shortly be published. Phosphatic rock, not entirely unlike the nelsonite of Nelson county, occurs about four miles east of Roanoke, where considerable prospecting was done about five years ago.

GRAPHITE

Graphite is rather widely distributed through the Piedmont region, occurring chiefly in the schists and gneisses, but as yet no actual production of the mineral has been reported. The occurrence of graphite has been noted in the following counties: Albemarle, Amelia, Buckingham, Charlotte, Loudoun, Louisa, Nelson, Orange, and Powhatan.

Probably the most encouraging occurrence of the mineral is in the northern part of Albemarle county, between Free Union and Boonsville, near Buck mountain. The graphite occurs here in irregular veinlike masses in gneisses and syenites and their residual decay. It is of good quality, and blocks weighing several hundred pounds are easily extracted. An analysis of the crude graphite made by Froehling and Robertson, of Richmond, gave 76.28 per cent. of graphitic carbon. The Naylor-Bruce Graphite Company acquired the property several years ago and made some developments on it, but closed down within a short time without any production.

RUTILE (Titanium)

The only locality in Virginia and, indeed, in the southeast Atlantic states, where rutile has been mined is in the Tye River-Hat Creek area of Nelson county. The area is a large one, located in the foot-hills region of the Blue Ridge, and is distant about seven miles northwest of the main line of the Southern Railway.

Two distinct types of rutile are mined. In the first type, designated pegmatite rutile, the rutile occurs chiefly as disseminated grains of variable size in a rock of very coarse- to medium-grained crystallization of feldspars and blue quartz with, in places, much hornblende. In the second type, designated nelsonite rutile, the rutile occurs in an even-granular rock, having dike-like characters, and composed normally of ilmenite and apatite. Near Rose's Mill, on Tye river, the ilmenite of the nelsonite is almost or entirely replaced by rutile, the rock ranging from an ilmenite-apatite mixture, in which little or no rutile is present, to a rutile-apatite mixture, containing but little ilmenite, with intermediate gradations in the ratio of ilmenite to rutile.

The American Rutile Company began mining of the pegmatite rutile in 1901 from side-hill cuts along the east side of Tye river, a short distance below the entrance of Hat creek, and, in 1902, a milling plant was built for concentrating the rutile. The rock, as exposed in the openings, is coarsely crystalline composed chiefly of feldspars (potash and soda-lime species) admixed with blue quartz in small grains and large masses, with feldspar greatly predominating. At the south end of the openings, the rock contains much partly altered dark green hornblende in large cleavable masses. The rock is igneous in origin and of intermediate basicity, containing 59.84 per cent. of SiO_2, and shows pronounced effects of metamorphism. The rutile is very pure, of red to reddish-brown color, and occurs chiefly as large and small grains, disseminated principally through the feldspar, but also in the blue quartz and the hornblende. The rutile is admixed in places with some ilmenite which is difficult of separation from the rutile.

In 1907, the General Electric Company began mining operations for rutile in the nelsonite dikes, near Rose's Mill. The dikes of nelsonite in this locality carry large percentages of rutile, in places, the rock is composed almost entirely of rutile and apatite, the former predominating, but has been found to grade into the normal rock—a mixture of ilmenite and apatite. For further description of the nelsonite dikes, see under Phosphate, on page 128.

The rutile deposits of the Nelson county area are being studied and mapped in detail by the Virginia Geological Survey, and a volume setting forth the results at considerable length will be published shortly.

MONAZITE

Monazite, essentially an anhydrous phosphate of the rare earths of the cerium group, containing usually a variable amount of thorium, which element gives the mineral its commercial value, has been found in Virginia only in Amelia county. It occurs at the Amelia county mica mines in large coarse crystals and masses, but, so far as is known, not in commercial quantity.

MINERAL WATERS

The mineral waters of Virginia are an important source of revenue in the State. Virginia has a very large number of spring resorts, and a great variety and abundance of well-known commercial waters. Indeed, Virginia is par excellence a mineral-springs state, occupying among the South Atlantic states the same position that New York does in the North Atlantic section. Virginia is second only to New York in the number of springs that are utilized commercially, and exceeds New York in the number of resorts.

All classes of mineral waters are found in the State, and some of these are among the most celebrated in the country. They are naturally divided into (1) those containing mineral salts in such proportion as to give them medicinal value, and (2) those approximately pure waters which are sold extensively for table or domestic use.

The production of mineral waters for 1908 shows a marked decrease from that of the previous year, and amounted to 2,099,614 gallons, valued at $207,115. This decrease is due largely to the failure of one of the largest producers in the State not reporting returns for 1908. The figures, compared with the totals for 1907, 2,442,075 gallons, valued at $431,770, show a decrease in quantity of 432,461 gallons, and in value of $224,655. It will be observed from the table below that the figures of production and value of mineral waters in the State notably increased in 1907 over 1906, due, it is reported, to sales at the Jamestown Exposition.

The following table gives the production and value of mineral waters in Virginia from 1903 to 1908, inclusive:

Production and value of Mineral Waters in Virginia, 1903 to 1908.

Year	Springs reporting sales	Quantity sold Gallons	Value
1903	41	2,561,502	$477,410
1904	35	2,117,420	281,998
1905	37	2,340,287	589,102
1906	43	1,997,207	418,908
1907	44	2,442.075	431,770
1908	46	[a]2,099,614	[a] 07,115

[a] Amount used for soft drinks not included.

About 47 per cent. or less than one-half of the 1908 output, valued at $97,502, was used for medicinal purposes, the remainder being classed as table water. The total number of springs reported as producing in 1908 was 46, as against 44 in 1907. These were distributed among the following 22 counties: Alexandria, Amelia, Augusta, Bath, Botetourt, Campbell, Chesterfield, Culpeper, Henrico, Isle of Wight, Loudoun, Mecklenburg, Montgomery, Nottoway, Princess Anne, Prince Edward, Roanoke, Rockingham, Sussex, Tazewell, Warwick, and Wythe. Eighteen of the twenty-two counties reported 21 resorts at or near the springs, with total accommodations for 2,616 people, and the water at 11 is reported as being used for bathing.

Out of a total of 68 mineral springs credited to Virginia, 46[a] reported sales during the year 1908. The list of springs follows, with those producing in 1908 marked by an asterisk (*).

*Ætna Lithia Springs, Vinton, Roanoke county.
*Alleghany Spring, Alleghany Springs, Montgomery county.
Artesian Mineral Springs, Smithfield, Isle of Wight county.
*Artesian Well, Mulberry Island, Warwick county.
Augusta White Lithia Spring, near Augusta Springs, Augusta county.
*Basic Lithia Spring, Basic City, Augusta county.
*Bath Alum Springs, McClung, Bath county.

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[a] Two additional springs produced during 1908, but did not report their production to the State Survey.

*Bear Lithia Spring, near Elkton, Rockingham county.
*Beaufont Lithia Spring, Beaufont, Chesterfield county.
*Bellfont Lithia Spring, Manchester, Chesterfield county.
*Berry Hill Mineral Spring, near Elkwood, Culpeper county.
*Blue Ridge Springs, Blue Ridge Springs, Botetourt county.
*Brugh's Spring, near Roanoke, Botetourt county.
*Buckhead Springs, Buckhead Springs, Chesterfield county.
*Buffalo Lithia Springs, Buffalo Lithia Springs, Mecklenburg county.
*Burnett's Mineral Spring, near Hudson Mill, Culpeper county.
*Campfield Lithia Spring, Temples Station, Chesterfield county.
*Como Lithia Spring, East Richmond, Henrico county.
*Coppohaunk Lithia Springs, Waverly, Sussex county.
*Crockett Arsenic Lithia Spring, Crockett Springs, Montgomery county.
*Days Point Artesian Lithia Spring, Days Point, Isle of Wight county.
*Diamond Spring, near Waterway, Princess Anne county.
East Leake Lithia Springs, East Leake, Goochland county.
*Erup Mineral Spring, Glencarlyn, Alexandria county.
*Farmville Lithia Springs, Farmville, Prince Edward county.
*Fonticello Lithia Spring, near Richmond, Chesterfield county.
Ferro-Magnesia Springs, Fincastle, Botetourt county.
*Golindo Lithia Spring, near Cave Station, Augusta county.
*Harris Anti-Dyspeptic and Tonic Springs, Burkeville, Nottoway county.
Healing Springs, Healing Springs, Bath county.
*Holly Lithia Springs, three miles east of Richmond, Chesterfield county.
Houston Chlorated Lithium Wells, Houston, Halifax county.
Hume Spring, Barcroft, Alexandria county.
Hunter Pulaski Alum Spring, Walkers Valley, Pulaski county.
*Irois Fontaine Lithia Springs, South Hill, Mecklenburg county.
*Iron Lithia Springs, Tip Top, Tazewell county.
*Jeffress Lithia Silica Spring, Jeffress, Mecklenburg county.
Jordan White Sulphur Spring, Jordan Springs, Frederick county.

*Kayser Lithia Springs, Staunton, Augusta county.
*Lone Jack Spring, Lone Jack Station, Campbell county.
*Magee's Chlorinated Lithia Spring, Clarksville, Mecklenburg county.
Manganese Sodium Iodide Spring, Hallsboro, Chesterfield county.
*Massanetta Spring, Harrisonburg, Rockingham county.
*Mecklenburg or Chase City Mineral Springs, Chase City, Mecklenburg county.
Montvale Hygeia Springs, Montvale, Bedford county.
*Nye Lithia Springs, Wytheville, Wythe county.
*O'Connell Lithia Spring, near Stribling Springs, Augusta county.
*Otterburn Lithia and Magnesia Springs, Amelia, Amelia county.
*Pæonian Spring, Pæonian Springs, Loudoun county.
*Pantops Mountain Spring, Charlottesville, Albemarle county.
Pickett Spring, Worsham, Prince Edward county.
*Powhatan Spring, Ballston, Alexandria county.
*Roanoke Lithia Spring, two and one-half miles west of Roanoke, Roanoke county.
Roanoke Red Sulphur Springs, ten miles north of Salem, Roanoke county.
Rockbridge Alum Springs, Rockbridge Alum Springs, Rockbridge county.
Rockingham (Virginia) Springs, near McGaheysville, Rockingham county.
*Rubino Healing Springs, Healing Springs, Bath county.
*Seawright Magnesian Lithia Springs, Staunton, Augusta county.
Seven Springs, near Glade Spring, Washington county.
Shenandoah Alum Springs, near North Mountain, Shenandoah county.
*Stribling Springs, near Mount Solon, Augusta county.
Sublett's Lithia Springs, near Danville, Pittsylvania county.
*Virginia Lithia Springs, Osceola, Chesterfield county.
*Virginia Magnesian Alkaline Spring, near Staunton, Augusta county.
Virginia White Rock Spring, Mount Solon, Augusta county.
*Wallawhatoola Alum Springs, near Millboro Spring, Bath county.

Waterlick White Sulphur Spring, Waterlick, Warren county.
*Wyrick Spring, Crockett, Wythe county.

There are given in the following table the production, value, and uses of mineral waters in Virginia in 1908, by counties.

Production, value, and uses of Mineral Waters in Virginia in 1908, by counties.

County	Medicinal and Table		Soft Drinks	
	Quantity Gallons	Value	Quantity Gallons	Value
Alexandria	2,300	$ 125		
Augusta	101,710	15,119		
Bath	17,217	9,682		
Botetourt	60,200	15,040		
Chesterfield	440,970	66,217	(b)	
Culpeper	33,700	3,370		
Mecklenburg	19,600	8,120	(b)	
Montgomery	11,000	2,750		
Roanoke	48,200	4,790		
Rockingham	1,070,000	55,100		
Wythe	4,117	412		
Other counties[a]	200,600	26,390		
Total	2,009,614	$207,115	119,672[b]	(Not tab.)

[a] Includes Amelia, Campbell, Henrico, Isle of Wight, Loudoun, Nottoway, Princess Anne, Prince Edward, Sussex, Tazewell, and Warwick.

[b] Includes Chesterfield and Mecklenburg counties.

PRECIOUS STONES

A variety of minerals of gem grade has been found in the crystalline rocks of the Piedmont province of Virginia. Some counties in this area, which seemingly offer good possibilities for the occurrence of gem material, have not yet been exploited for this purpose. The known counties which have either produced gem minerals, or contain minerals which might be of desirable gem grade, are Amelia, Amherst, Bedford, Buckingham, Fairfax, Hanover, Nelson, and Spottsylvania. Of these, Amelia county is the best known and has produced the largest variety and quantity of gem material. This material has come from the mica mines opened in the pegmatite dikes near Amelia Courthouse.

Those minerals known to occur in Virginia which have been used, or are capable of being used, for gem material are separately described below.

QUARTZ

Several varieties of quartz are found in Virginia, from which a few gems have been cut. These include a greenish colored banded quartz, a milky-white chalcedony, colorless quartz with dark inclusions, and a smoky-brown quartz. These have come from one locality, namely, Fairfax Courthouse. Gems cut from each variety of quartz from this locality are included in the collection of gems in the United States National Museum.

Amethyst, a variety of quartz, has long been known to students and collectors as occurring in Virginia. A promising locality has recently been opened, and some good gem material taken out at a point about two miles from Roseville, in Amherst county, and about the same distance from the James river. It occurs in pockets connected with a well-marked vein of white quartz which extends for some miles along the base of the Blue Ridge. The amethyst has been only slightly exploited.

GARNET

Beautiful transparent spessartite, a manganese-aluminum garnet, used as a gem, is found at the mica mines near Amelia Courthouse. Irregular masses of the spessartite with crystalline exterior have been obtained from the Amelia mines, which, on cutting, finished fine gems very similar in color and lustre to the essonite or hyacinth of Ceylon. The cut stones varied from 1 to 100 karats in weight.

Andradite, a calcium-iron garnet, usually of black color, has also been reported from the Amelia county mines. Topazolite, a subvariety of andradite, having the color and transparency of topaz, also occurs in the same mine.

ALLANITE

Allanite occurs in Amelia, Amherst, Bedford, and Nelson counties. It is found in considerable quantity in Amherst county, where it occurs in large masses and crystals, very compact and black in color, and would form a black metallic gem stone. It is also found in large masses in the Amelia county mica mines.

KYANITE

Kyanite is found at Willis mountain in Buckingham county, in the vicinity of the Hewlett mica mine in Hanover county, and two miles north of Chancellorsville in Spottsylvania county. As yet, no really fine gems have been produced from any of the American kyanite.

FLUORITE (Chlorophane)

One of the most remarkable varieties of this mineral, chlorophane, is found at the mica mines in Amelia county. It fluoresces by the heat of the hand, thus affording a fluorescent gem stone, but not hard enough for any kind of wear.

FELDSPAR

The numerous pegmatite dikes of the Piedmont region frequently contain feldspar of gem grade. The most noted locality in the State where feldspar of gem grade is found, and which has produced moonstones in some quantity, is that of the Amelia county mica mines. Three species of feldspar from these mines have yielded gems. These are the green-colored potash feldspar, microcline (variety Amazon stone), and the soda and soda-lime feldspars, albite and oligoclase (variety moonstone). The finest examples of moonstone from an American locality, very closely resembling the Ceylon in color and transparency, are found at Amelia.

MICROLITE

This rare mineral, essentially a calcium pyrotantalate containing niobium, fluorine, and a number of bases in small amount, is found only at the Amelia county mines. It occurs here in fine crystals up to one inch in diameter and in imperfect crystals up to four pounds in weight. Some of the microlite from this locality is sufficiently transparent to be highly prized as a gem, the color varying from an essonite red to that of a rich spinel yellow, and remarkably brilliant. It has a higher specific gravity than that of any known gem, being about 6.

APATITE, BERYL, COLUMBITE, AND HELVITE

All of these minerals occur in the Amelia county mica mines, but neither of them has yet been found to be of gem grade.

There was no production of precious stones in Virginia during the year 1908.

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VIRGINIA GEOLOGICAL SURVEY

THOMAS LEONARD WATSON

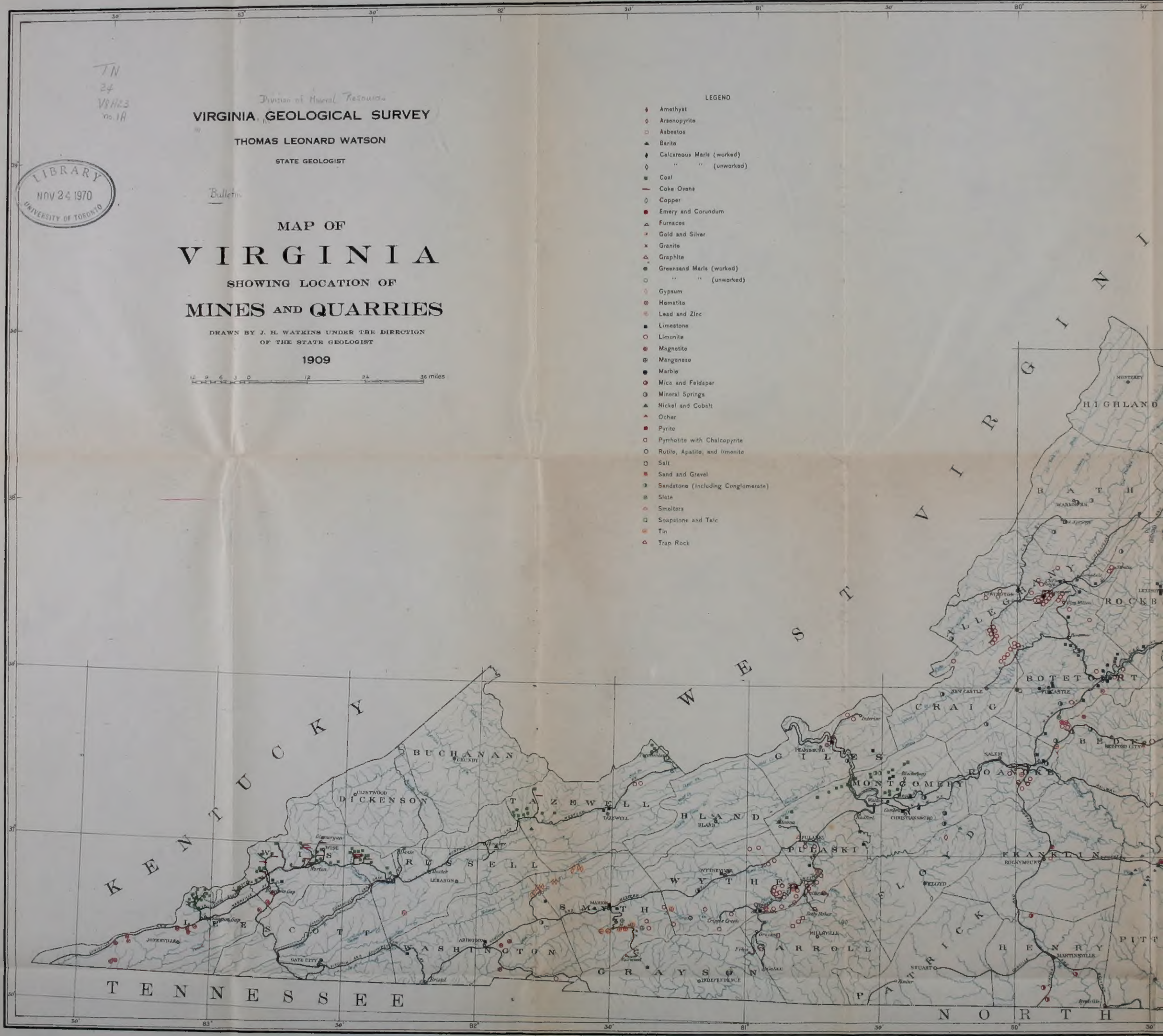
STATE GEOLOGIST

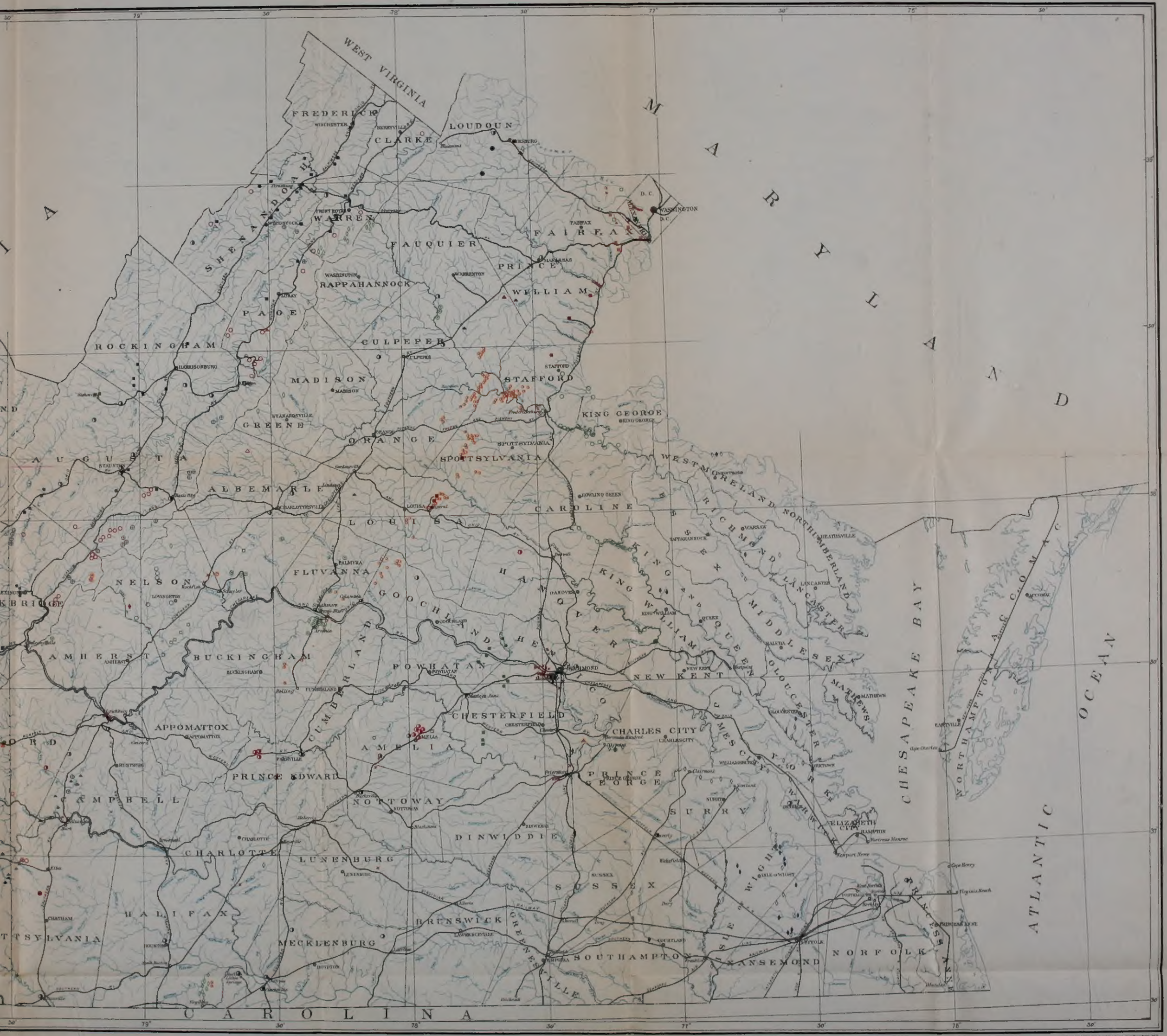
Bulletin

MAP OF
VIRGINIA
SHOWING LOCATION OF
MINES AND QUARRIES

DRAWN BY J. H. WATKINS UNDER THE DIRECTION
OF THE STATE GEOLOGIST

1909





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